A COURSE OF THIRTEEN PRACTICAL TALKS TO THE WORKING MEN OF THE EDISON ELECTRIC LIGHT CO. OF PHILADELPHIA

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OF

THIRTEEN PRACTICAL TALKS

TO THE

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EDISON ELECTRIC LIGHT COMPANY

OF PHILADELPHIA

PRESS OF
E. F. GREATHEAD
909 SANSOM ST.

CONTENTS.

PREFACE.

THE following thirteen lectures on Electrical and Mechanical topics, are the result of a united effort on the part of the Board of Control of the Edison Electric Light Company of Philadelphia, to instruct and interest the subordinate employes of their Company, and while very elementary in character are of great practical worth to any person desiring to become conversant with modern electric lighting.

It is to be hoped that the reader will realize the unselfish effort of these gentlemen to open the way for him, and once having the opening, will go on in self education in the arts, based on real knowledge and conducing to the advancement of civilization.

PHILADELPHIA, W. D. M.
JULY, 1895.

INTRODUCTORY REMARKS,

BY

PROF. WM. D. MARKS,
PRESIDENT.

I will have to begin my talk with you by an apology. Not for myself at all, because I am growing quite old and am accustomed to public speaking. I have been a lecturer a great deal of my life. That does not worry me; but what does worry me is, that one cannot manage to do anything with Mr. Edison:

The Board of Control came to me. I told them that I knew Edison and thought I could have some influence with him. I said I would do the best I could. Edison has never delivered a lecture in his life. After a great deal of thought, I wrote him a long letter, I took a great deal of pains with it, and felt very much impressed by my own letter. I thought he must come after that, but within a week afterwards I received the following letter from Mr. Edison:

Friend Marks:

In reply to your favor of the 12th instant, I beg to state that until I get a chance to get a little sleep without having my boots on, it will be impossible for me to come. My Ogden scheme keeps me on the jump. When that is over, I am coming to see you.

Yours truly,

THOMAS A. EDISON.

There is no use trying diplomacy on a man like that. We failed to get him, and to help the Board out I agreed to tell you what I know of him. As he is not here in person, I will call your attention to a bust of him here, which I know to be a remarkably good one. It was made during the progress of the Electrical Exhibition, by a sculptor who has since committed suicide, having all of the faults of a man whose genius is all in one direction. But this portrait is admirable. It is Edison over again.

In addition to that, some fifteen or twenty months ago, Mr. Edison compromised with me and agreed not to come, but to deliver an address for me to the Young Men's Christian Association—he would talk through a cylinder. This I asked him for a month before the time, and a day before the time I asked Mr. Johnson, as I did not want to disappoint the audience, if he would kindly go over to Mr. Edison's and remind him of his promise. We then discovered that Edison had disappeared somewhere in New Jersey—nobody knew exactly where—and I asked Mr. Johnson, if necessary, to get a special train and go after Mr. Edison. It did not make any difference about the expense. We had promised the cylinder and we were going to have it there if it cost a special train. He did not have to do that. He succeed in getting the cylinder—one that tells a story. It does not give an address as I had hope for. It tells a story of a man who went out to California. He was afflicted with a liver disease. He searched up and down the coast until he found a spring which he thought was beneficial to him. He drank of the water and was quickly cured; and, being a New England man, he immediately purchased the spring and set up a water cure. And, finding the water continued to agree with him he continued to drink it, and after many years of success as a landlord, he finally died, but the effect of the water was so strong that they were obliged to take out his liver and kill it with a club after he was dead. Now, in addition to this, I am going to ask Mr. Johnson to put Mr. Edison on the cylinder. He is a man who has a good many different things to talk about. You will notice that, after he has finished this story, he forgets himself—talks to somebody else—then recollects himself and says, "Yours truly, Edison;" and I think, immediately at the beginning, you will hear in a faint voice, intended for me or some workman "Give this to Johnson" meaning that this particular cylinder had to pass over to Mr. Johnson. I will sit down until Mr. Johnson makes Mr. Edison's speech.

Mr. Edison, through the cylinder, said:

You ask me to send you a phonographic cylinder for your lecture, and to say a few words to the audience. I do not think the audience would take any interest in any dry scientific talk, but perhaps they might be interested in a little story that a man sent me on a phonographic cylinder the other day from San Francisco. In the year 1873, a man from Massachusetts came to California with a chronic liver complaint. He searched all over the coast for a mineral spring to cure the disease, and, at last, down in the San Juaquin valley he found a spring the qualities of the water of which cured him almost instantly. He thereupon started a sanitarium, and people from all over the world came and were cured. Last year this man died, and so powerful had been the action of the waters that they had to take his liver out and kill it with a club.

Yours truly, EDISON.

In talking about Edison, I am not going to tell you the stories that you probably can find in any scientific work or magazine published lately. You can get dates and early incidents from any number of magazines. Cassier's magazine, published in New York, goes into his life in great detail. I will tell you, though, that, on the eleventh of next February, Mr. Edison will be 48 years old.

His early life as a child was the pathetic life that every little lad experiences who has a father that is either incompetent or too idle to attend to his education. He was knocked about as a newsboy, and train boy earning his living as he could. If he had any prominent peculiarity it was the fact that he seemed to be dull. Whenever he was not actively engaged in working for a living, he had a habit of going into reveries, and sometimes you would have to speak to him three or four times before he would apparently hear you.

He spent whatever little money he could get in experimentation. He and a boy friend, while endeavoring to learn telegraphy between themselves, established a line between two neighboring houses. There were two high fences between the two houses where they established their line, and Edison says that very frequently—in fact almost always—after one had sent a message to the other, he had to climb over those two fences and tell him what the message was. However, it was an indication of his desire to learn, and by saving the life of a little child, the daughter of a station agent, he obtained lessons from this station agent who was also telegraph operator. He learned then, in what might be called a methodical way, how to send messages over the telegraph wires.

He had another peculiarity besides that of falling into brown studies. He made up his mind that he was going to be a learned man and a well read one. When he was stationed in Detroit, he had access to the Detroit Free Library, and having no guide he determined that he would read the library through. He started in at one end of the library and read fifteen feet in length by measurement along one shelf before a kind hearted librarian found out what he was up to, and suggested to him that that was not the way to become a learned man. Through his kindness, he was put upon a course of history and classical reading. A few of the books that he read while he was yet quite a child, I have mentioned here in this memorandum. They do not bear on electricity, but they are worthy of reading by anyone. He read Hume's History of England, Gibbon's History of the Reformation, Gibbon's Decline and Fall of the Roman Empire and Estry's History of the World. Along with these he took in anything of a chemical or scientific nature to which he could gain access.

He soon developed great skill as a telegraph operator, and as a result, got pay adequate to support him and to enable him to carry on some of his experiments.

There is a gentleman who was in this city not long ago—if I remember rightly his name was Mr. Adams—who told me that at one time in Edison's career he missed him for a while, and he went and hunted him up. He was then receiving good pay as one of the best of telegraph operators. He discovered him in a garret, more than half chemical laboratory, sick, unable to move, half-starved, and without money, for he had spent it all for his chemicals and apparatus. He nursed him and brought him back to health—one of the fortunate incidents of life on which all of us are dependent.

Going on in his experiments, he soon undertook to improve the instruments of telegraphy. He invented the quadruplex.

A friend of mine, going over to his laboratory, while I was professor in the University of Pennsylvania, at the time when Edison was receiving royalties from the Western Union for his quadruplex instruments and other improvements in the art he was then practicing, told me that Edison opened a pocket-book which he had in his pocket and showed him 150 $1,000 bills which he had just received from the Western Union Company as a royalty for a portion of the year—I do not recollect what portion, but at any rate he was able then to experiment all he pleased.

Shortly after that, he established a shop in Newark. He had some forty or fifty men working for him. It was always an ambition on his part, to create an industry which would make him a leader of industry and an employer of a large number of men. He got up telegraph instruments and other pieces of electrical apparatus based on his inventions, and at the end of a year his scientific bookkeeper showed him a very large profit on the business. Edison is generous, he was feeling very good over it; and he immediately issued invitations to everybody in the shop for a grand dinner at the Grand Hotel of Newark. He thought he had made some $30,000 or $40,000. The bookkeeper said he had. Everything was prepared for the dinner, when it occurred to him that he had better find out what bank balance he had, and he found to his amazement that his balance was exhausted. He had made $30,000 or $40,000, but he had spent it on something else. So, he withdrew his invitations to the dinner.

Of late years he has been in the pay of various corporations—such corporations as the Western Union, the General Electric and some others. They have agreed to pay him salaries ranging from $10,000 to $20,000, $30,000 and $40,000 a year. He to go on with his experimentation and they to have the first opportunity, at a fair valuation, to purchase whatever he might invent. They simply pay this salary for the purpose of being able to get hold of his inventions first. They have so much confidence in the value of the man's inventions and inventive ability.

Now taking the man up himself—I might say gossiping about him with you—he is regarded by many men as a self-contained, selfish man. In that respect they are wrong. He becomes so much wrapped up in the thing that is in his mind and that he is trying to carry out, that the men around him are as shadows to him. They come and go and he hardly sees them. He thinks of nothing but what he is doing and the man that comes to him or goes away from him has no more effect on him than the machine turning around in front of him, and of course this indifference does create in the minds of a good many men an idea of selfishness, but when he comes out of these moods, he is the very prince of good fellows, both in his ways and in his generosity.

A great many other people think that Edison must be a crank. All of you have met inventors—a man with something that he has invented—it is usually one thing—he cannot think of anything else or talk of anything else but the thing he has invented, and you call him a crank, and you are right. That is what a crank is. But Edison is not a crank. If Edison had been a general, he would have been a greater general than Grant or Lee; if a financier he would have been a greater one than

Commodore Vanderbilt or Jay Gould; but destiny made him an inventor, and he is, as we know, the greatest inventor known in the history of the World—a man whose intuition seems almost divine in its depth.

To put him before you as nearly as I can, I will say that his head is of more than the usual size. It is not only very long from front to back, but it is also very broad behind the ears and very broad across the forehead. It is not a very high forehead but a very broad one indeed.

If you will pardon me for speaking of myself, I have usually to wear a hat measuring 7¼ in some direction—some hat maker's measurement—and wherever I go I throw that hat down and do not care how many hats there are lying around, for I feel certain nobody is going to take my hat. It goes down over their ears and they soon take it off and get another. One day I attended a directors' meeting in New York City, and in coming away I picked up a hat which I thought would go on my head. Without looking particularly at it I put it on and started down Wall Street. When I was quite a distance, along came Edison. He said: "You have got my hat." He had my hat on, but he had it on the back of his head as a halo is usually worn. My hat was long enough from front to back but too narrow across the forehead, and his hat fitted me by leaving a half inch space over each side. So we exchanged hats and I went on and he went back.

With regard to his physique, he is under the average height, very broad shouldered, very thick through the chest and evidently possessed of a great deal of vitality. With his wonderful power of concentrating his attention upon a single thing and persisting in it, he also possesses another power that very rarely is possessed by the same man—that is, quickness of perception. If he makes an experiment, he will see in that experiment ten times as much as the average scientfic experimenter. It will suggest to him ten times as much. I went to his laboratory at the time he was first experimenting on incandescent lamps. He had rows of them there He was then quite deaf, but not so deaf as now. He would walk up and down before those rows of lamps and say "That one is going in a minute." I looked at it but could not distinguish any difference between it and the others. Mr. Howell, who will lecture before you, was with me, and I asked him about it. He said he could not see any difference. Only Edison could see that. That is the type of the man—that is the power that he has.

Now I think that the man himself is as nearly presented to you as he can be without being here in person. I will make you another promise, and that is I will do my best to beguile Mr. Edison over here some other Friday evening. I will not let any one of you know when to expect him, but I will have him come and deliver a lecture no matter who the regular lecturer is. Those that are here will see him; those that are not, will miss him.

I will tell you of his inventions. Not the early inventions. I will begin at the wrong end. In his letter he wrote to me from his concentrating works—from Ogden, N. J.

All through New Jersey there are large beds of magnetic ores—iron ores attracted by the magnet. There are many different kinds but this particular New Jersey iron ore is attracted by the magnet. It is, however, a very lean ore—there is a great deal of dirt and rock mixed in with it—and although the ore itself is of the finest quality and will make the finest steel, they have not been able to mine it at a profit heretofore, for the reason that it was too much trouble to separate it. Mr. Edison, many years ago, undertook to buy these magnetic ore beds in New Jersey, and also mines out in other parts of the country for the same purpose, but his principal purchases were in New Jersey. He then went to work with the aid of his friends building an ore concentrating works. He has been at that thing three or four years. He is worth three or four millions of dollars himself. Individually, he has so far put one and a half millions of dollars into his investments in ore beds and in machinery at Ogden, New Jersey, and up to six or eight months ago he had gotten nothing out of it. I am glad to say however, that he writes me that it is a success practically.

The way in which he treats his ore is to pass it through large rollers some 20 to 30 inches in diameter, to crush it very fine indeed, and then allow it to fall before magnets or upon the magnetic iron cores. It flies over to the end of those large magnets and the gangue or dirt or dust falls straight down. I will make a little sketch on the blackboard which will show you the general principle—not the machine, but the principle on which the whole of the concentrating process is carried out.

The crushing and grinding process is just the same as the crushing and grinding used in any ordinary process. After it is done, the crushed material, dirt and ore, get run into the spout (indicating) and runs down in front of the magnets. Here is a series of magnets and here is a "V" shaped piece. These magnets attract the fine ore and it sticks to this one first. Pretty soon a big load comes there and it gets too heavy, falls a little farther and gets bigger yet and falls on down, and finally gets down there and falls off—runs off in the spout This ore is clean of all dirt. He takes that and makes it into a cake about that size (indicating 6 inches) and about an inch thick. He works it up with rosin, and he has orders to ship all of that that he can make to the Bethlehem Iron Works, and they convert it into metal for making steel. That is the principle of his last invention. In order to carry that out on a very large scale, it has been necessary for him so far to spend a million and a half dollars.

You have all of you seen another invention of his which I never have regarded as being quite up to his standard, and that is the kinetoscope.

All through the various watering places and cities of the coast, you will see advertisements of the kinetoscope, and by going in and paying five cents you can see a dance, a boxing match or dog fight—almost anything—going on for about thirty seconds.

The principle of the kinetoscope is the same as that of the old zootrope. It was a circular shallow box with a series of slots cut in it, and a light thrown on it, and you looked through a slit while it whirled

and you could see almost any sort of an animal in motion. The way that was done was this ; A horse trotting for instance. Taking just a leg in order to save time. (Illustrating on blackboard.) Successive positions of the various limbs of a horse are laid out in this way in successive figures, and you see in rapid succession one horse throwing out his foot, another horse putting his foot down and so on, and the result, one following the other as fast as one-tenth of a second—which is the length of time it takes the eye to see anything—it looks to you as if you saw the horse in motion, but instead you saw two dozen horses in different positions. Edison has taken a series of photographs one after another at intervals of one-tenth of a second or perhaps less, of those men engaged in a prize fight, or those of chickens or ducks—anything of that sort—and he has arranged the mechanism on which the whole is formed, and then this zootrope arrangement presenting it in quick succession to your eye, and the result is, he has so perfected, by means of instantaneous photography, and so regulated the speed by means of electric motors, that you get a much more perfect illusion than the old zootrope, when one had to slowly paint the position—each position—of the animal under observation. That is all there is in the kinetoscope—nothing more than this.

Now, there is one more invention to which I wish to call your attention before asking you again to listen to it—and that is the phonograph. Great things were hoped of the phonograph. Great things should have come of it. But, financially, it has proved an egregious blunder. Edison received from Mr. Lippincott, if I remember rightly, three-quarters of a million dollars for his patent on the phonograph, and Mr. Lippincott soon failed and thereafter died, after undertaking to make a success financially of the phonograph. There was no fault in the phonograph ; the fault was that the business men of the United States were not a class of skilled engineers and mechanics, and the result was they got into trouble right away with the phonograph, and they declined to go on using it, and as the Phonograph Co., had not sold them outright, but were renting them, they were immediately thrown back on the hands of Mr. Lippincott, and he had a large investment producing no return.

It is a very useful instrument in the hands of a person with sufficient skill and patience to make use of it and learn how to use it. It is particularly useful, as you have already seen, this evening, in preserving the voice and speech of others, and it is also particularly agreeable as an entertainment in reproducing music of brass bands, instrumental music or singing of a comical nature. Of course, when you have singing of a supposed melodious character, the tin-pan like voice of the phonograph does not flatter the artists, and they have given up the attempt to sing into it with a view of having their voices preserved.

I will not go on with any more of Mr Edison's inventions, because we have all agreed not to take more than an hour of your time ; but I wish to say to you that at 48 years of age, I regard Mr. Edison as a man who is constantly pushing beyond the utmost verge of human thought, as a man of almost—I was going to say divine—attributes, attributes such

as are attributed to the god Prometheus, the god of invention—ability to forever find out new truths in nature. And he is also one of the greatest captains of industry that the world has ever seen.

I have not looked into the matter closely, but I do not doubt that to-day there are invested in his inventions over five hundred millions dollars of capital, and, when you come to labor, there are employed over 50,000 men, supporting over 200,000 women and children, or a total of a quarter of million of people, who, in these hard times, would probably be out of work, were it not for the genius of this one man—Thomas A. Edison.

BOILERS OF THE EDISON ELECTRIC LIGHT CO. OF PHILADELPHIA,

BY

THOMAS O. ORGAN,

SUPT. OF BUILDING.

In constructing the steam power plant our first attention must be given to the boilers; and in selecting a steam boiler, we must study the economy in the use of coal and safety in steam generation. It has been estimated in 1870 that 200,000,000 tons of coal were annually used for making steam. At a low estimate this coal would cost $500,000,000, from which it will be seen how largely even a small per cent. of savings would add to the wealth of the world. While manufacturers and engineers have given considerable attention to the improvement of the steam engine, whereby they might reduce the consumption of steam for a given amount of power, they have comparatively given little attention to the economy of its generation. In fact we find at the present day, boilers in use, which are substantially the same as were used a century ago. Lately we find steam users have begun to realize that there are other principles and aims of equal prominence and greater importance to be considered in choosing a boiler to the selection of a steam engine.

In the selection of a steam boiler we must study the following requirements. The best material that experience and scientific investigation have sanctioned. A boiler must be simple in construction, of the very best workmanship, durable and not liable to require early repairs.

All boilers should have a mud drum, where all impurities from the water can be deposited, in a place far away from the action of the fire. There should be sufficient steam and water capacity. The steam should have plenty of room to disengage itself from the water and prevent foaming, and the water level prevented from fluctuating.

The water should have a constant circulation, so as to maintain all parts of the boiler at one temperature. The water space should be divided into sections, so that no general explosion can occur, and the destructive effects confined to the simple escape of the contents. All passages should be large enough to equalize the passage of the water and maintain a true water line.

A boiler should have excessive strength over all legitimate strains, and so constructed as not to be liable to unequal expansive strains. By all means the joints should be far removed from the fire.

The combustion chamber should be so arranged, so that the combustion of the gases may be completed before escaping up the chimney. The heating surface should be arranged at right angles to the heated gases, and the current of heated gases broken up and its valuable heat extracted before passing into the atmosphere.

Every part of a boiler should be accessible for cleaning and repairs. This point is of the greatest importance, as regards safety from explosion and economy of fuel. That ordinary boilers do explode is witnessed almost every day by the sad list of casualities. In the year 1887, there were no less than 198 explosions recorded, killing or badly wounding 652 persons. There is no need to resort to mysterious causes for the destructive energy displayed in a boiler explosion.

It has been estimated that there is sufficient stored energy in a plain cylinder boiler with a hundred pounds pressure of steam to project it to a height of over 3½ miles. A cubic foot of heated water under a pressure of 70 pounds per square inch has about the same energy as one pound of gunpowder.

In speaking of water tube boilers, the store of available energy is usually less than that of any of the other stationary boilers, and not very much from the amount stored pound for pound in the plain tubular boiler. It is evident that their admitted safety from destructive explosion does not come from that relation however; but from the division of the contents into small portions. And especially from those details of construction which make it tolerably certain that any rupture shall be local.

If steam boilers are properly proportioned and constructed, they will, when new, be safe against considerable more pressure than the safety valve is set to. The hydrostatic test properly applied may discover faults in material, but against the danger resulting from unequal expansion, ordinary boilers have no protection, a fact not properly appreciated by engineers and the public.

In a great many boilers we find some parts very hot, while other parts are very cold. Under these conditions enormous strains must occur in some parts of the boiler, which are thereby weakened. These strains constantly repeated must certainly destroy the strength at some point and eventually cause a rupture. Generally the rupture is small and gradual, but sometimes large and productive of disastrous explosions.

Want of circulation of the water in a boiler is a frequent and prolific cause of unequal expansion and deteriorating strains, and little if any provision is made for circulation in ordinary construction of boilers.

A constant source of danger in most boilers is low water. Constant vigilance is required to keep the water at the proper height. Otherwise the fall of a very few inches will cause the crown sheet or some other portion to become dry. These parts being exposed to the direct heat of the fire, become overheated, weakening the metal to such an extent that an explosion is likely to occur.

Unequal expansion and weakening of boilers is often caused by a deposit of scale on the heating surface, causing burring and blistering of the iron. This is liable to occur in any boiler. In a great many there is no provision made for the removal of scale when found. This is particularly the case with tubular and locomotive boilers. How often do we hear of disastrous explosions with one half the pressure that has stood the inspector's test of just a few days before. We find no corrosion or other natural causes with which we are acquainted, save expansion, can produce this result.

If we wish to provide against explosions, we must first have ample strength. This can be attained with thin heating surface and by small diameter of parts, being very careful not to carry it so far as to antagonize the equally important feature of a large capacity and disengaging surface.

The most important element of safety in a steam boiler is its structure. It should be so constructed that the original strength cannot be destroyed by deteriorating strains from explosions or otherwise. Every part of a boiler should be so arranged that unequal expansion could not occur by providing such elasticity that will overcome all deteriorating strains.

When designing a boiler, the parts should be so arranged that when through gross carelessness, the water becomes low, and the boiler becomes overheated, a rupture if it occur, can produce no serious disaster.

A stayed surface should not be permitted in a boiler. It is scarcely possible that such stays are or can be so adjusted as to bear equal strains. The one sustaining the heaviest strain gives way. The others will follow, as a matter of course, and a disastrous explosion ensues.

The mere presence of a water tube boiler does not make everything safe. A water tube boiler may be combined with other features which make it exceedingly dangerous. They may have a flat surface stayed or unstayed, or like a porcupine boiler, have their shells perforated like perforated card board ; and to make matters worse, expanding the tubes into these holes seriously strains the metal, making the construction still weaker.

When purchasing a steam boiler, we must not forget its safety by any means. We do not know of any boiler that is perfect in all the points that I have mentioned. A boiler may be designed so that every part has freedom to expand and contract, relieving the boiler from excessive strains ; but through dishonest workmanship, the sections are put together in such a manner to make the boiler perfectly rigid. Those workmen do away with the elasticity properly provided by the designer and often cause an explosion. The boilers on the 4th floor of this station, Fig. 2, which gave us so much trouble, were imperfect in workmanship and

design. We found the bolts body bound in both the lugs on the bends and headers, Fig. 7, the under side of the bend resting on a key lug, and the bolts hanging on one side of the head. Fig. 11. We also found the seat for the packing ring eccentric, Fig. 8, and a very heavy packing ring, Fig. 7, making a flange joint. In fact, the bend was so rigid that the boiler had no freedom to expand or contract, without putting excessive strains on the bolts, breaking them off like icicles. Fig. 11. The total steam pressure on each bend is about 3010 pounds. Each bolt in connecting a bend has a tension of 3000. This tension on the bolt is caused by tightening of the bend. By multiplying 3000 by 4 will give us 12,000 pounds. Add 3010 pounds steam pressure to the 12,000 pounds, and we get 15,010 pounds.

The breaking strain of these four bolts is 64,000 pounds. We now take 15,010 pounds, which is the steam pressure and strain on the bolts by connecting the bend, from 64,000 pounds, and we find that it will take 48,990 pounds more than we required to break the bolts.

Is it possible that 15,010 pounds would break 4 bolts that had a total strength of 64000 pounds, if there was no other cause than the pressure of steam?

Gentlemen, the cause of the bolts breaking in our boilers was, in the first place, bad workmanship, and in the second place, expansion and contraction of the tubes. The breaking of bolts in our boilers is by some attributed to some mysterious chemical action of the water we use. Others to vibration of the building, and by some, electricity. The supervising engineer of this concern setting aside the beclouded theories of self styled experts regarding certain explosive gases, mysterious chemical changes, electricity, &c., and came down to a solid basis of cause and effect. By doing so we found the bends connected in the manner I have described to you. No man, that knows anything about a steam boiler, and had a conscience, would ever do such work as we found on those boilers. When rebuilding those boilers, I personally examined every slot in the headers and holes in lugs of the bends. Every bolt has now a ball and socket joint. Fig. 5 and 10. Every ring has been made elastic, and the bend free to move with the expansion and contraction of the boiler. Fig. 5. You will notice in the drawings that the headers are not flush the one with the other. Fig. 9. This is caused by the expansion of the tubes, the tubes receiving the most heat are the longest. I will endeavor to show you the strain put upon those boilers by the expansion of the tubes. The co-efficient for expansion of wrought iron is merely a figure showing the fractional parts of the total length of a piece of that material, which it will expand when heated 1 degree Fah. (.0000068) Every degree of heat applied up to a certain limit, a piece of iron will expand .0000068 of its length. If we take a piece of iron 1 inch long, at a temperature of 60 degrees and heat it to 61 degrees, it will become 1.0000068 inches long. Our boiler tubes are 18 feet long and contain 216 inches. The tubes are generally made of No. 10 iron, which is about .134 inches. The tubes are 4 inches outside diameter and the inside 3.732 inches. If we take the area of the small circle, and subtract it from the large circle, we find the metal composing the tube to be 1.6275 square inches.

We will suppose that the average temperature of our boiler, when cold, is 60 degrees; and when heated to a temperature of 360 degrees, which is about 130 pound pressure by the steam gauge, we have seen for each degree Fah. each tube will elongate .0000068 of their original total length. If we use the co-efficient of expansion and multiply it by 216 inches, the length of our tubes, you will find for each degree one of these tubes will expand .0014688 of an inch.

If one degree cause such elongation, for 300 degrees it will be elongated .44064 inches which is almost ½ of an inch.

We have seen that our boiler tube is 216 inches long; and that it elongates at a temperature of 300 degrees Fah., .44064 of an inch. In order to find what part of our last given figures are of the total length, we must divide 216 inches by .44064 of an inch, and we get a little over $\frac{1}{490}$ of its total length.

A well recognized American authority says that if we wish to stretch a bar of iron one inch square to double its length (if it was possible,) it would require 29,000,000 pounds. Now $\frac{1}{490}$ of 29,000,000 pounds is 59,183 pounds per square inch of area. Our tubes contain 1.6275 inches area, multiply this by 59,183 pounds and we get a weight of 96,283 pounds, which would be required to pull each one of these tubes out the same length that it has elongated by the action of the heat, when doing its regular work. Therefore the heat strain on each one of these tubes is equal to about 43 tons.

You will see by this how essential it is to make every part of a boiler free from all expansive strains.

When the first Battery of Boilers was installed in this Station, they had no swinging beam for the front part of the tubes to rest on, to give the tubes freedom to expand. Fig. 2G. Consequently the front walls were bulged out, and the boiler fronts broken so badly that we were compelled to brace the fronts with wood and iron.

This swinging beam (Fig. 2G.) of which the builders now boast, I believe was suggested by Prof. Marks, the President of this Company.

In the first part of my address, I said that every boiler should have a mud drum, so that all impurities of the water could be deposited.

The builders of the boilers on our 4th floor, claim that the mud drum is in its proper place and all the dirt is deposited there, (Fig. 2 F.) and cannot be carried up into the tubes; but our experience proves that this is not the case. If you disconnect the bends on the top row of tubes at the back, you will find them almost full of mud. Fig. 2 H. Examine headers and bends, that should keep clean (if there was a good circulation) and had a mud drum that would receive the dirt, and you will find them full of mud.

In the Babcock & Wilcox Boilers the construction is changed. Here we do not have so many obstructions for the passage of water, the water making a complete circuit, (Fig. 3) the feed water entering the front of the boilers (Fig. 1 G) is carried back with the circulating water and down the back headers depositing its dirt in the mud drum. Fig. 1 D.

Upon examination of the headers front and back of these boilers, we find no deposit. Fig. 1 E. These boilers do not carry the dirt up into

the tubes like the boilers on the 4th floor. In fact if you should keep the Babcock & Wilcox Boilers on the line for 3 months continously, they would not be so dirty as the 4th floor boilers would be in three days. If you notice the construction of the 4th floor boilers, you will see there is 44 obstructions to the passage of the water and steam in each section. Fig. 4. You cannot carry a true water level, sometimes the water is at the top of the glass and sometimes at the bottom, which makes it very difficult to feed the boiler. The Babcock & Wilcox boilers have no obstruction to the passage of the steam and water and carry a true water line.

When the 4th floor boilers are on the line the steam pressure should be maintained at the given pressure, as the rise and fall of a few pounds will cause the boiler to leak badly at the bend connections. It will not only cause leaks at the bend connections, but put uneven expansion and contraction strains on the boiler.

Although the boilers in this Station are not liable to destructive explosions, great care should be exercised to avoid damage to the boiler, and expensive delays. The boilers should be kept perfectly clean inside and out. otherwise there will be a serious waste of fuel. The presence of scale or sediment in the tubes results in a loss of fuel, burning and cracking of the boiler, predisposes to explosion and leads to extensive repairs.

The presence of $\frac{1}{16}$ inch of scale causes a loss of 13 per cent. of fuel, ¼ inch, 38 per cent. and ½ inch, 60 per cent. For every locomotive in the Middle and Western States, there is an average annual loss of $750.00, due to incrustation.

Analysis of a great variety of incrustations show that carbonate and sulphate of lime form the larger part of all ordinary scale, that from carbonates being soft and granular, and that from sulphates hard and crystalline. Organic substances in connection with carbonate of lime will also make a hard and troublesome scale. The most common and important minerals in a boiler scale are carbonate of lime and sulphate of lime, and carbonate of magnesia. Sometimes small amounts of Alumnia and Silica are found, and Oxide of Iron not infrequently is present as a coloring matter.

Though a boiler may have a rapid circulation of water and delay the deposit, and certain chemicals change its character, the most certain cure is periodical inspections and mechanical cleaning. Cleaning may be rendered less frequent by the use of some preventative.

The following are some of the samples now in use and their results.

Barks of wood, such as Oak, Hemlock, Sumac, and Logwood are effective in waters containing carbonates of lime or magnesia, by reason of the tannic acid which they contain. This tannic acid is very injurious to the iron, and should not be recommended.

So far as a scale is concerned, the following have been used, by reason of the acetic acid which they contain:—Vinegar, Fruits, Cane Juice and Molasses. These scale preventatives should not be used, as the acetic acid is even more injurious to the iron than tannic acid. The organic matter forms a scale when sulphate of lime is present. Soda ash and other alkalies are very useful in water containing sulphate of lime, as

they will combine with it and form a carbonate in the shape of a soft scale, which is very easily removed.

Great care must be used when using Soda Ash or other alkalies, as they will cause foaming, particularly where there is oil coming from the engines. Petroleum has been highly recommended as a scale preventative where sulphate of lime predominates. I find that petroleum is of no use when carrying over 80 lbs. steam pressure, as the Petroleum vaporizes, when heated to 316 degrees Fah.

Water tube boilers are used in this Station for the following reasons:

The thick plates such as are ordinarily used in steam boilers would not transmit the heat quick enough to the water, should we get a sudden demand for steam; and would admit of overheating and burning the side next to the fire, which would put excessive strains on the boiler, resulting in loss of strength, cracks, and a tendency to rupture, which is the direct cause of most explosions. Water tubes like used in our boilers form thin envelopes for the water next to the fire, and transmit the heat so readily that the fiercest fire cannot overheat or injure the surface, as long as it is covered with water upon the other side.

Suppose we had tubular boilers with double thick riveted joints exposed to the fire, and we should have a sudden demand for steam, as we often do in the summer months, it would not be safe to raise the pressure quickly on these boilers, as the double thick riveted joints being the weakest part of the structure, concentrate upon themselves all strains of unequal expansion, giving rise to frequent leaks and not rarely to actual rupture. The tubes and tube sheets, when exposed to the direct action of the fire also cause much trouble. The boilers in this Station have no thick plates or double thick riveted joints. All joints are farremoved from the direct action of the fire.

The draught area, which is limited in all fire tube boilers to the actual area of the tubes, in these boilers has the whole chamber, which gives ample time for the gases to give up their heat during their passage, before making their exit up the chimney.

A perfect combustion depends upon a thorough mixture of gases with a proper quantity of atmospheric air. The analysis of gases from various furnaces show almost uniformly an excess of free oxygen, proving that sufficient air is admitted to the furnace, and that a more thorough and perfect mixing is needed. Every particle of gas evolved from the fuel should have its equivalent of oxygen, and must find it while hot enough to combine, in order to be effective. In our boilers the gases are broken up and thoroughly mixed by passing between the tubes, and have an opportunity of complete combustion in the chamber between the tubes and the drums.

The water in our boilers being divided into small parts and passing through the hottest part of the furnace, steam may be started very rapidly; and sudden demands upon the boiler may be met by a quickly increased efficiency. The Babcock and Wilcox Boilers on the 6th floor have large drums, which gives them a large disengaging surface. They have also a dry pipe, (Fig. 1B) which secures a thorough separation of the steam from the water, when the boiler is forced to its utmost.

The boilers on the 4th floor have one-half of the 14 inch drums as a disengaging surface. Fig. 1B. The steam is then carried up through the nipples at the back into the 36 inch steam drum. Fig. 2A. This 36 inch steam drum is supposed to dry the steam before it enters the main steam line. No doubt there is a wave motion set up in the 14 inch drums, (Fig. 2G) often carrying the water up through the nipples into the 36 inch steam drum. This wave motion in the 14 inch drums is caused by the obstructions to the passage of the water and steam up through the bends and headers. Unless sufficient steam and water capacity is provided, there will not be regularity of action, the steam pressure will suddenly rise and as suddenly fall; and the water level will be subject to frequent and rapid changes.

Water capacity is of more importance than steam space, owing to the small relative weight of the steam. Too much water space makes slow steaming and waste of fuel in starting. Too much steam space adds to the radiating surface, and increases the losses from that cause.

One great advantage of a water tube boiler is its accessibility for cleaning. Every tube can be removed by simply removing a cap or a bend; every drum can be examined by the removal of a hand hole plate. In a fire tube boiler, the tube can be quickly covered to one half of its surface with dust or soot, the water tube will retain only a limited amount on its upper side, and then becomes in a measure self cleaning. By the occasional use of steam through a blowing pipe, the tubes can be kept free from dust and in condition to receive the heat to the best advantage.

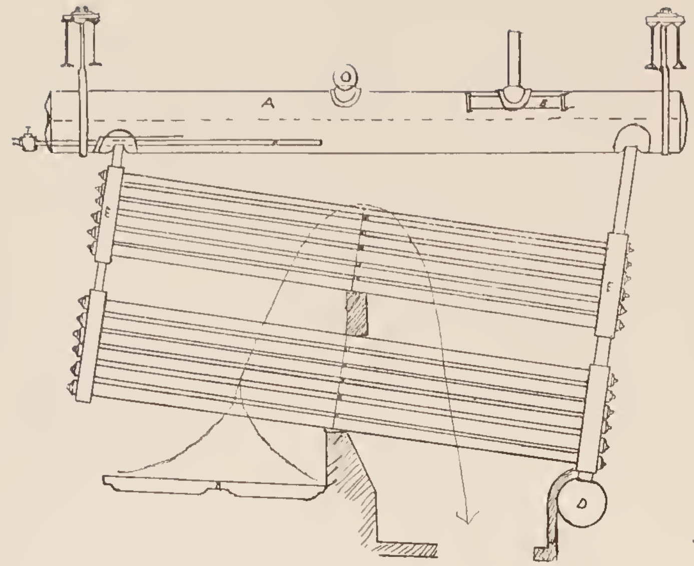


Fig 1
6TH FLOOR BOILERS

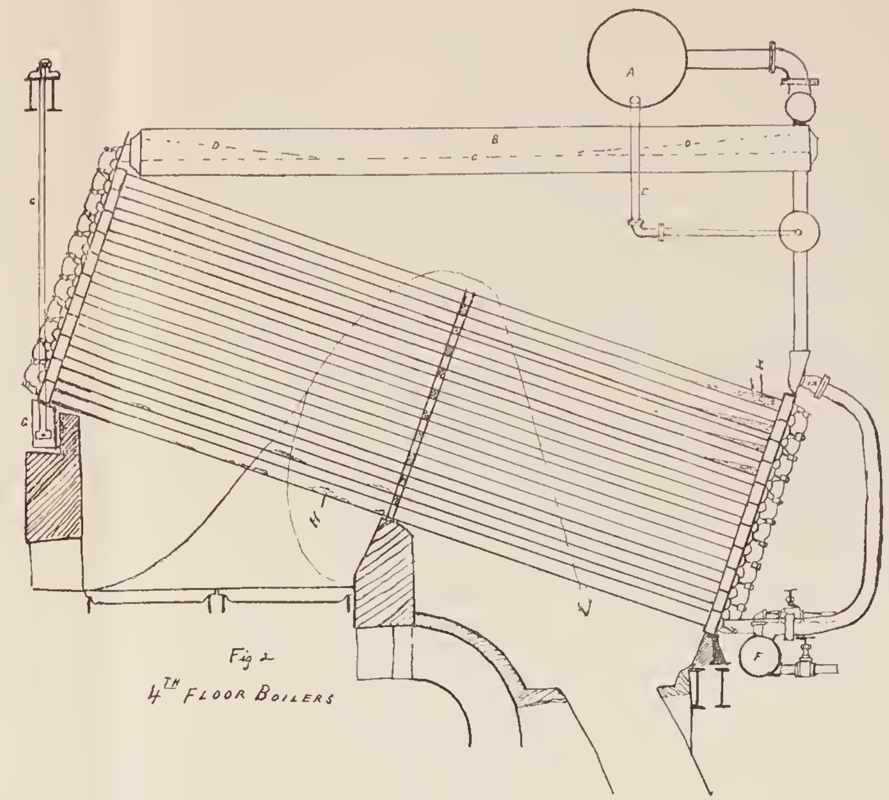


Fig 2
4TH FLOOR BOILERS

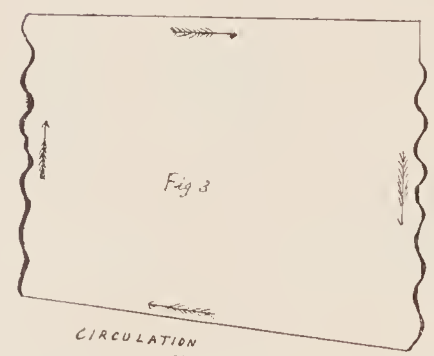


Fig 3

CIRCULATION
6TH FLOOR BOILERS

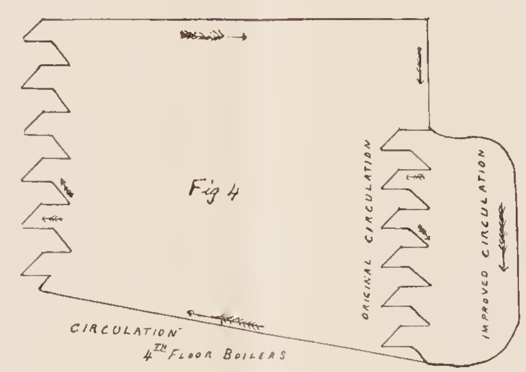


Fig 4

CIRCULATION
4TH FLOOR BOILERS

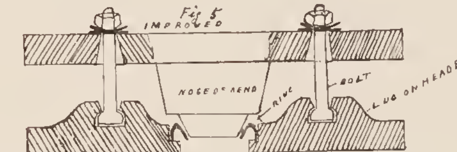


Fig 5 IMPROVED

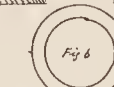


Fig 6 IMP SEAT FOR RING

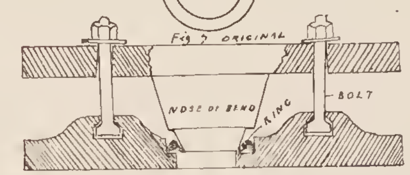


Fig 7 ORIGINAL

Fig 8 ORIGINAL SEAT FOR RING

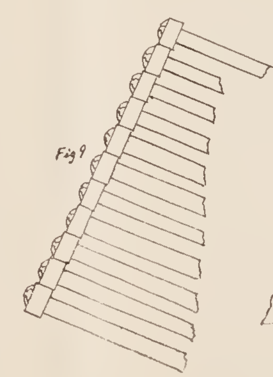


Fig 9

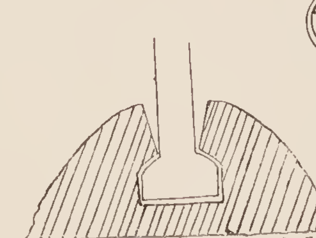


Fig 10 IMPROVED BOLT AND LUG

ORIGINAL BOLT
Fig 11. AND LUG

MACHINE WORK AND MACHINERY ERECTION,

BY

A. FALKENAU,

MECHANICAL ENGINEER AND MACHINIST.

In all industrial establishments where machinery is used, an appreciation of the work requisite in building the machines and an understanding of the care requisite in erecting them, will enable the employee to better perform his duty with greater satisfaction to himself as well as his employer. This is particularly the case where the product is not a material one and the care of apparatus and machinery is the sole occupation of the employee. One of the highest types of this class of industry is that of furnishing electric light.

I do not propose to deal with the design or construction of engines, boilers and dynamos. What I desire to call your attention to is rather the machine and other work required in shaping the various parts, insuring proper fits and relative positions so that the completed work will be a machine or appliance properly suited for the purpose for which it was intended. The erection of this work will form the second part of my subject.

Let us follow the work of construction of a machine from the point where it leaves the draughtman's hands. We should have a complete set of drawings. One or more of the drawings should show the relations which the parts should ultimately bear to each other, which is usually called the erecting or general drawing. Then we should have drawings showing each part of the machine in detail. The detail drawings should indicate the relative distances, surfaces to be finished, holes to be bored or drilled, etc.

The first mechanical operation to be performed in accordance with these drawings is the making of patterns for such parts as are to be of cast metal. It is of the utmost importance to the pattern maker to know what material each piece is to be made of and the draughtsman should

indicate in the drawings, whether the piece is to be of iron, steel, brass babbit, etc. The pattern maker will make the pattern larger in its dimensions than those shown on the drawings in accordance with the kind of metal so as to allow shrinkage, which occurs as the metal cools after it is cast. For cast iron the shrinkage is one-eighth of an inch per foot, for brass three-sixteenth of an inch per foot, and for cast steel the shrinkage varies considerably and is frequently as much as one-quarter of an inch per foot.

In determining the dimensions to be given to the pattern, the pattern maker must also consider the form of the piece to be cast. If the pattern can be easily withdrawn from the mould he must make the dimensions of his pattern greater at the point where finish is to be allowed for, than he would if the pattern had to be rapped in order to free it from the sand so as to be able to withdraw it. Moreover if the piece is a light and long one so that the casting is liable to warp in cooling he must allow more for finish than he otherwise would. The patterns having been made they should be thoroughly examined to see that they are of proper dimensions and that the considerations I have just mentioned have received due attention. In obtaining proper castings much depends upon the skill of the foundryman. With the best of patterns he may fail to produce a good casting, if the mould is not properly rammed or vented, the iron run too cold or the casting improperly cooled.

We will suppose we have succeeded in obtaining a good set of castings for the machine we intend to build.

In order to properly accomplish the machine work it is of the utmost importance that the foreman should have a clear idea of the ultimate purpose of the machine he is building. The degree of accuracy required in the work should always be determined and be dependent upon the operation which the finished machine is to perform.

For example, the work on an ore crushing machine can be of a much rougher kind than that on a steam engine; and a lathe for tool room work should be of much finer workmanship than one for rough turning. The demand made for accurate work is growing more exacting each year. In the time of James Watt a cylinder bored one quarter of an inch out of round was considered a good job, while nowadays there are cases where a cylinder must be made true within .001 of an inch.

Many mechanics lack a clear idea of what accuracy should be demanded. Sometimes they are unreasonable in their demands and at other times they do not insist upon sufficient accuracy because they fail to appreciate the need of it. I have had persons request me to make them a perfectly accurate screw and expecting to obtain the same within two hours of giving the order. The work of grinding an accurate screw say a foot long such as required for a fine dividing machine takes several weeks. Certainly such accuracy is not required for ordinary machine work.

I propose to give you an idea of some of the precautions necessary in handling ordinary machine work. The work on heavier machine parts is as a rule more easily accomplished than that on light ones. For exam-

ple the planing of the guides on a heavy steam engine bed require that the bed should be properly secured to the bed of the planer and ordinary care exercised to procure the aligment of the plane surfaces with the center line of the cylinder. When the planing is done the bed may be removed from the planer and any further work to be done on the same proceeded with. Not so with a light table for a knitting machine. When the rough planing has been done the piece should be removed from the planer and left to season for days or weeks if possible and should then be returned to the planer for finishing up the work. This is the only way to obtain reasonably true work on light pieces.

In much of the work to be done on planing machines the work of setting takes a large proportion of the total time of work. And although, as a rule people seem to think that covering the floor with chips is the best evidence of progress of work they will often find that more time spent on setting would have been well spent. What I have said in regard to the importance of setting, applies equally to many pieces that have to be finished in the lathe, boring mill or other machine tool. Thus in a crank disk of an engine it is very important that the hole for the crank pin should be quite parallel to the hole bored to receive the shaft. It is easier to obtain accurate circular work such as is done on a lathe, than straight line work and this should always be borne in mind when designing machines.

Most circular work is ready for use as it comes from the machines, whereas in straight line work we find many pieces which must be scraped, as for instance valves and valve seats or must be at least filed to make proper fits or finish, as for instance the strap ends of connecting rods. The amount of scraping to be done will largely depend upon whether the casting has been well handled in planing or not.

From a distance, that is upon seeing the completed work, all the operations of turning, boring, planing, drilling, etc. seem simple enough, but they do not only require well designed rigid machines and proper setting of the work but much thought and skill in the maintainance of the cutting tools. Thus in drilling, an operation with which you are all practically familiar, given the best made drill press and you will not obtain a true, smooth hole unless your drill is straight, has the lips evenly ground and proper clearance at the cutting edge. Some of the best machinists are careless about giving attention to these points. In planing or turning the tools may be too springy and cause chattering or the tools may not be properly formed.

One of the operations to be performed in the machine shop quite frequently and which nearly every mechanic has to deal with at some time or other is gear cutting. You may be setting up a machine and find that the gears have too much back lash or that the gears run irregularly. The apparatus by which the divisions were determined may be very inaccurate or while the teeth were being cut the gear blank may not have been running true on its mandrel.

Defects in workmanship do not always present themselves during the erecting of machines but only after running them. Then sometimes these

defects are very hard to locate as probably many of you have experienced. Thus the knock in an engine, although generally due to the need of adjustment of some part in crosshead or connecting rod, may be due to the fact that the crank pin is not parallel to the axis.

A comparatively slight error of this kind will produce a disagreeable knock. It is not always easy to determine that the error exists after the engine is erected as a surface table, squares straight edges and surface guages, which are used for examining work in the machine shop cannot be readily applied. Still in many cases the determination is a very simple one, when for instance the inclination of the crank pin is into or out from the centre and the engine has bored guides. We will suppose the engine is a horizontal one, then it will be found that if the engine is turned over so that the crosshead is first in the middle of the forward stroke and then brought to the middle of the return stroke, the crosshead which certainly should occupy the same position in the two instances, will have revolved slightly about the axis of the piston rod.

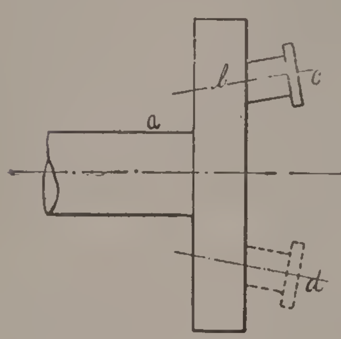


FIG. 1.

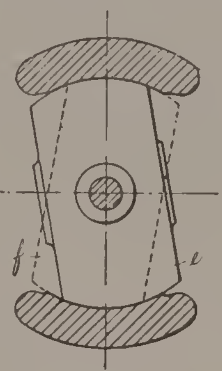


FIG. 2.

This will be more readily understood on examining Fig. 1, where *a*, is the shaft, *b*, the crank disc. *c*, the position of the crank pin on the forward stroke, and *d*, its position on the return stroke. In Fig. 2, *e* shows the position of the crosshead when the crank pin is at *c*, and *f*, the position when the crank pin is at *d*.

Now having in a general way referred to the methods and the care necessary in machine work and its subsequent erection let me pass on to the general considerations of the erection of machinery. Now you are no longer in the machine shop where tools are convenient for remedying any error you may discover, in fact as a rule you are placed with few conveniences at hand and mother wit is of great service.

Machinery can be divided into three general classes. 1st. Prime movers or Power producing machines. 2nd. Machinery of Transmission and finally Operative Machinery. In the class of prime movers belong, Steam Engines, Gas Engines, Windmills, Water Wheels, &c. Machinery of Transmission includes shafting, pullies and belts, rope drivers, hydraulic piping, etc. and under the class of Operative Machinery are included all the machines built for performing some special work.

In erecting prime movers, the first question which usually presents itself is the securing of proper foundations. Good heavy foundations are always a good thing as far as the preservation of the machine is concerned, but the cost of such foundations is not always warranted. In mining machinery where engines and pumps are frequently moved it is customary to make rather crude wood foundations. Wherever the location of a machine may be considered permanent, however, a well layed foundation

of stone, brick or cement is preferable. In mining practice where wooden foundations are used, the timbers, furnishing the foundation are framed together and well bolted in the form of a crib. The crib is then filled in with stone or earth, thus affording a large mass by which any vibrations of the machine are readily absorbed, and earth is frequently also tamped all around the foundation.

In the cities where the vibrations due to the running of an engine are objectionable it is now common practice to build the foundation entirely independent of any neighboring walls and to carry the same down to or even below the general building foundations so as to have the vibrations taken up by the earth below.

In building any foundation the safe load which the ground upon which it is built can carry must be considered. Sand, gravel or clay may be loaded with from one to three tons per square foot and the foundation should accordingly be spread out to produce such loading.

Where engine beds are not in one single massive piece it is good practice to cap the foundation with a cast iron plate to which the engine and bearings, etc., are secured. The relative position of parts is thus more easily insured. In erecting engines or in fact any machines the matter of alignment should receive careful attention.

It is a common occurrence for men to charge up all troubles they meet with to the bad workmanship in the shop, whereas much is to be charged to carelessness in erection. When assembling the parts of an engine each part should be carefully cleaned. Much of the heating and cutting we hear of is due to primeval dirt. When the parts have been assembled, care should be exercised to see that all passages and connections with the engine are clear and that pipes are so inclined as to lead entrained water to the point where it is desired to draw it off. When everything is in readiness the engine should be tested without a load and later on with a load with a view to finding any defects in the work of construction or erection. Faults in either of these directions will not always show at once. Thus badly fitted keys or mismanaged shrink fits may not show until the machinery has been run for some time. In the same way the yielding of foundations which have not been properly layed may not show itself for months after starting. Among the most troublesome defects to locate are defects in castings.

The castings as inspected in the shop may have appeared perfectly sound, yet I have known of troubles which the indicator recorded and others which announced themselves by noise, which it cost much thought and time to locate.

In one case the indicator diagram pointed to a leak and as it was supposed to be due to the fit of the slide valve, that was thoroughly scraped in, but this did not improve matters. For months the engine was watched and examined without any satisfactory result. On one occasion however the engine was stopped at the end of its back stroke and the piston was found to be in the condition shown in Fig. 3 and 4. There was a cold shot in the casting, the metal included between the lines *abcd* Fig. 4, not having united with the rest of the metal in the piston, acted like a

valve. When the steam pressure was on the back of the piston this was closed and the piston acted as it should, but on the return stroke the outer part of the piston was forced in the direction of the arrow, driving the piston rod solely by catching on the outer edges of the nut and opened the crack sufciently to permit steam to pass through. A case where a disagreeable knock showed that something was wrong proved on examination that the noise was due to an almost imperceptible crack in the cylinder head. The cylinder head as shown in Fig. 5 is cored out so as to permit the inner wall of the head to be crushed in, in case water should get into the cylinder. The core had been shifted in the mould so that the metal at d, e, Fig 6, was only $\frac{1}{64}$ of an inch thick, and in consequence of which a crack rapidly developed in the corner shown at a, Fig. 5, and extending around three-quarters of the circumference from c to f, as shown in Fig. 6. When the back end of the cylinder was being exhausted the weight of the inner part of the cylinder head would open up the crack and as soon as the pressure for the forward stroke was admitted to the cylinder, the crack would be closed giving a sharp knock, which thus occured only at one point during one revolution of the crank.

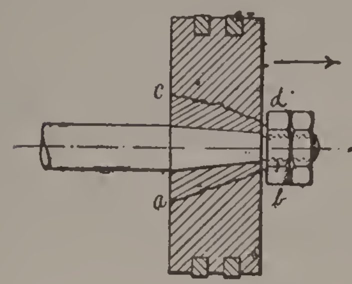


FIG. 3.

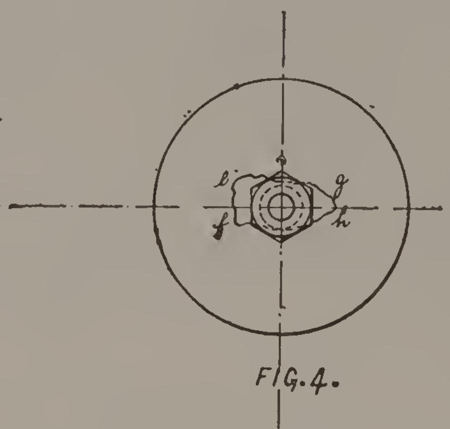


FIG. 4.

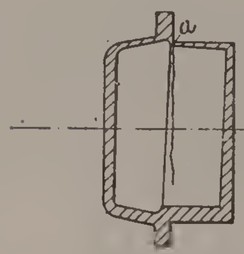


FIG. 5.

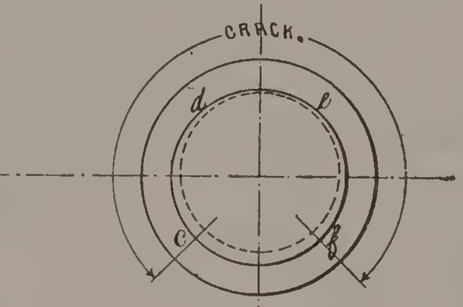


FIG. 6.

You will see from what I have already said that a familiarity with shop methods in the pattern shop, foundry or machine shop will greatly aid those who are employed about machines of any kind in intelligently reasoning about difficulties they encounter.

I will now say a few words in regard to the erection of the machinery of transmission. Nowadays there is hardly any one who must not in some way or other deal with shafts, pullies and belting. When installing a plant the most important point is that the shafts should be properly proportioned for the horse power they should transmit. All calculations with regard to these bring us back to the drafting room or engineer's office where all the circumstances should be carefully considered. Some of these considerations which enter into the planning of a line of shafting are the material the shafting is made of, the distances between bearings and whether the load is constant or is thrown on suddenly, the distribution of the load at different points of the line and the velocity of revolution. The location and diameter of pullies should also receive careful consideration.

The design being satisfactory much depends upon the way the shafting is erected. The line should be level and straight and the bearings or hangers should be rigidly secured. Any neglect of these precautions will throw additional friction on the shaft and when I tell you that there have been cases on very long lines of shafting, which have not been properly erected, where 90 per cent. of the work of the engine was required to drive the shaft alone, you will see how important it is to look after these points.

One source of trouble which is frequently to be found in lines of shafting, where the old fashioned flange coupling is used, is that the couplings are cocked on the shaft by the keyway, where the couplings have been finished up independently of the shaft. The only way I know of securing a good job with the flange coupling is to key each half to its shaft and then face it up. The modern compression coupling if properly applied will secure good alignment of the ends of the shafts. In lining up shafts the use of a fine string, if care is used gives very satisfactory results, but the use of instruments will serve as a good supplement to the work already done. A very convenient leveling instrument is specially made for shaft lining work, which consists of two glass tubes to be placed vertically on the two points of the shaft to be tested, the glass tubes being connected by rubber tubing and the apparatus containing water to show the level readings.

As to the pulleys it is important that the bore should be concentric with rim, and that it should fit the shaft. Any variation in this respect will alter the tension of the belts and hence the driving power. Pulleys on which the belts are to be shifted are usually made straight, but some mechanics claim to have been able to run belts satisfactorily by making the driving pulley slightly crowned and the loose pulley of a somewhat smaller diameter. The usual rule followed in making crowned pullies is to crown the rim one quarter inch for a foot width of face. In securing pulleys set screws are commonly used. At times however these cut into the shaft, so that it becomes impossible to remove the pulleys without breaking them. A good way to avoid this is the introduction of a shoe under the set screws.

In erecting counter-shafts the length of belt should be considered. Where possible the distances from center to center should not be less than twenty feet. Oak tanned belting has proved itself to be the best on the long run. The common custom is to allow a working strain of 50 to 60 pounds to the inch width of single belts and 80 lbs. for double belts. As a matter of economy by giving the belts longer life it has been advocated by some to allow only one half the amount of strain just mentioned. The almost universal practice is to allow about 60 lbs. strain per inch width of belt.

The ultimate strength of leather used for belting is about 3000 lbs. per square inch of section. For calculating the size of a single belt a general rule is to allow 60 square feet per horse power. A belt transmits force from one pulley to another solely due to the friction which the belt has on the pulley. As the friction by which we transmit the force can

only be a part of the total strain on the belt, the initial tension of the belt must be greater than the amount of force we wish to transmit. You probably all understand that when you first put a belt on two pullies the two sides are strained alike but as soon as you set your driving pulley in motion the driving side of the belt takes up a greater strain, while the other side becomes slack and is generally spoken of as the slack side of the belt. Roughly speaking the initial tension required is about one and one half times the working strain to be transmitted and when the belt is doing its work the driving side is strained to twice the amount of force to be transmitted.

Thus if we wish our belt to have a working strain of sixty pounds we should have to strain our belt up until the strain was 90 lbs., that is until each side had a strain of 90 lbs. Now as soon as the belt performs its work the strain on the tight side will be 120 lbs. and on the slack side 60 lbs. This is clearly shown in figures 7 and 8. It is well to know this as many belts are stretched tighter than necessary and produce unnecessary friction in the bearing of the shaft. It would be best if when tightening belts the strains put on were actually weighed.

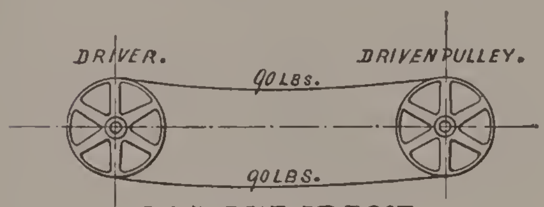


FIG. 7. BELT AT REST

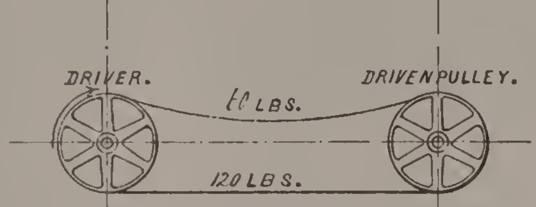


FIG. 8 BELT IN MOTION.

The rules I have given you are only approximate, for the tension required varies with the amount of the circumference of the pulley which the belt surrounds and also with the material and condition of the belt. Belts should be cleaned and greased about every six months. The use of rosin to increase the friction should be avoided as it injures the belts. If a belt needs tightening a general rule is to shorten it about one half an inch for every ten feet of length of belt.

The amount of horse power transmitted by a belt will depend upon its speed. One thousand to three thousand feet per minute are ordinary belt speeds but belts are sometimes run as high as four or five thousand feet per minute. To secure long life to belts large pullies are preferable. In order that the belts should run well the shafts on which the pullies are mounted should be parallel. But this alone does not prevent a belt from travelling off the pulley.

Much depends upon the quality of the belt itself and upon the way it is laced. The leather from the center or back of the hide is closer grained and more uniform than that from the belly. It frequently happens therefore that the leather on one edge of a belt is weaker than on the other edge and the stretch is therefore unequal and the belt may become quite loose on one side. Again in preparing to lace a belt the ends should be cut off square with a try square if possible. The holes should be punched out uniformly and the lace used of even width. Whether or not attention has been paid to all these little details will show itself very

soon after the machinery you have erected is started up. Belts without any lacing, namely cemented in place are preferable but certainly not always convenient.

One other important element in machinery of transmission is the gear wheel. The smoothness of running of gear wheels depends greatly upon the shape of the teeth. If the teeth are cut, very good results may be attained. In erecting these however care must be exercised to have the two gears at the correct center distance and the shafts parallel. Where the gears are cast from a pattern, a tooth of such gear will be thiner at one end than at the other owing to the draft required in the pattern, so that it can be withdrawn from the mould. In mounting cast gears the teeth should come together so that the draft of the tooth in one gear should be opposed to that in the other. Certainly you can never expect a cast gear to give as good results as a cut one. Machine moulded gears are better than those made from a full pattern but on account of shrinkage of the cast iron, these also are not quite regular.

Operative Machinery, the last class which I have mentioned, is largely self contained, little being required in erecting it outside of proper foundation and aligment of counter-shafts. Of this kind are lathes and machine shop tools in general, looms and spinning machinery, etc. Certainly there are some operative machines like rolling mills, stamp mills and the like, which are large and complicated and where a great part of the work comes in the erecting.

Any one of the subjects I have touch upon this evening would permit of an extended treatment by itself. My object however has been to call your attention to the inter-relation between shop work and erection work in producing the result desired by every mechanic where a plant for any purpose is erected.

Those who are employed about the erecting or operating of machinery should intelligently cooperate with those who originally construct it. Much can be learned by the builder of machinery from those who are able to observe the machines day by day as they perform their functions or fail to perform them. In fact, I believe there is more to be learned from failures than from any other source.

But you who have these failures occurring directly under your very eyes, have great advantages over those who have to reason from hearsay or casual examination. You can watch a knock in an engine from day to day and can test your reasoning about it in various ways and at various times. Or if the water guage in your boiler does not act right you are familiar with all the conditions of the water, steam pressure, cleaning, etc. and have many facts stored in your memory which should aid you in finding a reason for the peculiar behavior.

The wider your knowledge is the more rapidly will you get at the truth, and I trust that the hints I have thrown out this evening may be of some use to you, when some ill-natured machine makes life a burden to you.

STEAM PIPING AND MACHINERY,

BY

HARRY C. PHILLIPPI,

Chief of Steam Dept.

STEAM PIPING.

In the Philadelphia Edison Station there are six 10-inch main lines of steam pipe, one on the North, one on the South, two on the East and two on the West side. These latter lines cross the Engine Room from East to West, branching off North and South to supply the engines, so that we are prepared to furnish steam to any set of engines in the room, no matter from which quarter the steam is taken. After leaving the Boiler Room the steam flows down to the Engine Room, but just below the Dynamo Room floor, the 10-inch main lines enter a separator (Fig. 1) 18 inches in diameter by 9 feet long. The steam impinging on the top of the cone shield *G*, breaks it up, allowing the entrained water to separate and fall to the bottom, while the steam takes a reverse course under the cone shield down through the 10-inch internal tube *J*, to the main lines. By this means, we are enabled to keep the entrained water and the natural condensation from being picked up and carried into the engines, thereby saving cylinder heads from being blown out and general smash-ups, such as happened here before, and which will not happen again.

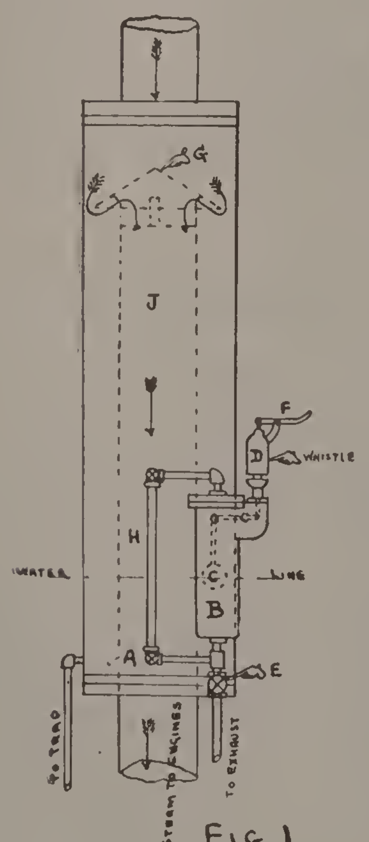


Fig 1

Fig. 1 shows a wrought iron casing ⅜ inch thick, 18 inches in diameter and 9 feet long, on

which you will notice a very important adjunct in the shape of a high water alarm with whistle attached. This whistle tells us when the water is approaching the danger line. Thus the water rises through the 1 inch connection *A*, into the main body *B*, (also showing in the water glass *H*), until it reaches the copper float *C*, which raises by floatation, throws the valve in the whistle *D*, open and the alarm is sounded. Immediately the engineer opens the valve *E*, and allows the water to escape to the exhaust pipe.

To see if the alarm is working properly at all times, there is a lever *F*, on top of the whistle *D*, which by lifting, the alarm is tested at various times during the day and night, which puts the engineer's mind at rest, he knowing that there is one whom he can trust to tell him of danger in time to avoid having the cylinder head blown to atoms ; and perhaps he along with it, without any invitation.

Water is one of the most dangerous elements the engineer has to deal with ; and to set aside all danger, provision is made for carrying off all water of condensation by means of drip pipes attached at convenient places. For instance, from all separators and all main line valves, there are independent pipes leading into a manifold, and from thence to the steam traps (Prof. Marks, Patent). The traps allow all water of condensation to collect at one central point, and discharge without wasting steam. In addition to this, there is a system of auxiliary drip pipes, which discharge directly into the exhaust pipes. These auxiliary drip pipes are for the purpose of securing extra safety, in case any one of the main line drip pipes should become closed, or a joint broken, or closing off for repairs.

It is a mystery to some people how or why steam once made, should return to water again. This is caused by radiation of heat, and by radiation, we mean losing or giving up heat from a body of high temperature to a body of lower temperature. When the temperature of the two adjoining bodies becomes equal, no more heat can be given up ; but in the case of steam pipes, the atmosphere is constantly changing, the heated air rising, leaving space for the cooler air to flow in and take its place. Consequently the radiation is constantly going on. Now there must be some means used to check this radiation, or the loss is very considerable from naked pipes, and in case of long lines of pipes, it becomes a serious matter, not only on account of the waste of fuel which is very important ; but because the condensed water interferes considerably with the working of the engine, unless there is some means of getting rid of it, such as I have spoken of. This is one very important reason why all steam pipes should be covered with some good non-conducting material; as it checks radiation and lessens condensation, as the thickness of metal within the limit of ordinary practice does not seem to materially affect the quantity of heat radiated from uncovered surfaces. It has also been proven that there is no practical gain by covering steam pipes over 1 inch thick. To show the great value of covering steam pipes, the following is cited. Suppose we have an uncovered pipe 10 inches diameter, 100 feet long, which presents 35.5 square feet of surface to the cooling influence

of the atmosphere. The steam pressure 125 pounds plus 15 pounds atmospheric pressure, making an absolute pressure of 140 pounds. The temperature of steam at this pressure equals 354.8 degrees Fah. The temperature of the Engine Room 90 degrees. Then the loss from radiation would be 28,201 heat units per hour, and as 1 pound of coal is not good for more than 1000 heat units, the result is we get a loss of 28.2 pounds of coal per hour or a total of 109.4 tons per year. If this coal cost $3.00 per ton, the loss would be $328.20. The loss in condensation would be 102 cubic feet. Loss in H. P. equals 1.04 H. P. By covering this pipe with 1 inch of good covering, the saving in coal would be 91.8 tons, leaving a loss of 17.6 tons per year against 109.4 tons for an uncovered pipe. Thus the loss would be 1.04 H. P., and that saved being .87 H. P., making a net loss of .17 H. P.

It is a noticable fact that if these losses occur from a pipe of this size, what must the loss be from the hundreds and thousands of feet of pipe in daily use uncovered and no attention paid to the loss, as it seems to be a necessary factor in the running of many manufacturing establishments.

There is a question that the engineer is very often called upon to consider, and that is whether the size of the steam pipes leading to his engine is sufficient to let through the amount of steam necessary to supply the engine, without a considerable fall of pressure. The engineer taking an indicator card, measures the height of the steam line above atmospheric line, and gets at once the pressure that was in the cylinder at the commencement of the stroke, and while the engine was taking steam. If this comes within a very little of the boiler pressure, he feels more satisfied; but if on the other hand it shows a considerable fall from the pressure in the boiler, it at once brings to mind that there is something wrong, and he at once asks himself, what are we carrying a certain pressure in the boilers for, if it is not to get into the engine? He thinks and looks about to see the cause of the loss of pressure. Naturally the first object he looks at is the steam pipe. If it is not sufficiently covered, there will be a loss of pressure from this cause, and it would be quite an easy thing for the engineer to put an indicator on the steam pipe and connect it with the reducing motion of the engine, and take a diagram from the steam pipe, just as he would a diagram from the cylinder. This card would show the fluctuations of pressure in the steam pipe and where the piston was when these fluctuations took place. This would prove whether any loss in pressure might be between the pipe and chest, or between the chest and cylinder. If the diagram showed that immediately after the piston moved there was a noticable fall in pressure in the steam pipe, and that this continued until the engine had cut off, then it would be conclusive evidence that the steam pipe was not large enough to supply the demand for steam and keep up the pressure. If on the other hand, the card showed that the pressure in the steam pipe varied little from that in the boiler, then the diagram would show that any loss in the initial pressure in the cylinder was due to the inability of the steam to get into the cylinder and would show that the steam ports were restricted in area.

Engineers have found that in supplying steam to an engine through a pipe, the steam should not be obliged to move faster than 100 feet in a second, that is to say that if a pipe was more than 100 feet in length, that particle of steam in the pipe 100 feet from the cylinder, should reach the cylinder in one second. It will make no difference whether the steam is cut off early or late in the stroke, for the steam must move at that rate of speed to fill the cylinder while the valve is open. If the cylinder was required to be filled once in a second, entirely filled without cut off, it should take all the steam in 100 feet length of pipe in that second. If it is cut off at half stroke, only 50 feet of the steam in the pipe will be taken, but that 50 feet has to be moved in one half of a second. So with one quarter cut off, only 25 feet of the length of the steam pipe is relieved of its steam, but it must be relieved in one quarter of a second. The rate therefore is the same for all points of cut offs, for if there is less space to fill because of the cut off, the time in which it is to be filled is lessened in proportion.

It is a fact that the area of the opening of a pipe multiplied by its length will give the volume that pipe will contain. Thus a steam pipe having an area of opening of 20 square inches and 500 inches in length would contain a volume of $20 \times 500 = 10{,}000$ cubic inches. Dividing this volume by its length will give the area of the opening of the pipe. If we know then how much volume of steam which must be supplied to an engine in one second, and wish to put it into a pipe 100 feet long, we have only to divide the volume by 100, and get at once what the area of the pipe must be to contain the volume of steam.

We will then have a volume of steam in 100 feet length of pipe which must be emptied of its steam in one second to satisfy what the cylinder demands; and the steam will therefore move at the rate of 100 feet in one second.

If an engine makes 60 revolutions a minute, the piston makes two strokes per second, and the cylinder must be filled twice in this second.

By multiplying the area of the piston by the length of stroke will give the volume to be filled in one stroke, and by two will give the volume to be filled in one second. It will be seen that if this is the proper area of the steam pipe, the area of the port must be just as much. It is here where the difficulty comes. The port should be open to an amount that will equal this area by such time as the piston starting from a state of rest gets to a movement equal to the rate of speed per second.

In conclusion I will say, however, there is a loss of pressure at the elbows and through globe valves; but this may be disregarded unless there are more than five of them, in which case they will produce a loss of pressure by the friction of the steam passing through them; and further the steam pipe should never be so small that its capacity will ever be taxed, or so large that it will become a reservoir for unused steam.

THE STEAM ENGINE.

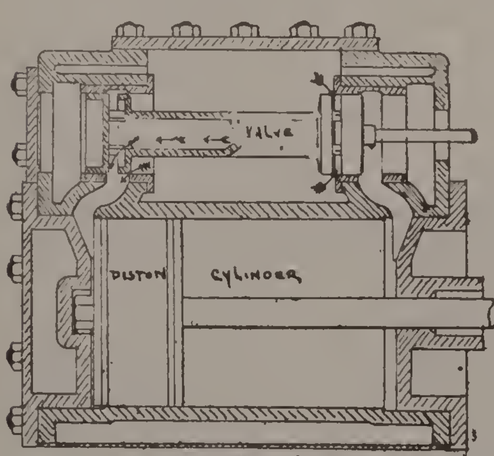
The steam engine is divided into two classes, namely, throttling and automatic cut off. The throttle governed engine is an engine in which the amount of steam is regulated by changing the pressure at which it

enters the cylinder, in accordance with the load, and is accomplished by the old fashioned ball governor.

An automatic engine is an engine in which the amount of steam is regulated by cutting off the supply automatically at various points in the stroke, in accordance with the load and pressure, and is accomplished by what is known as a shaft governor. In a throttling engine, the volume admitted is constant, and the pressure is varied, while in the automatic cut off, steam is admitted at the highest available pressure, and the volume is varied to suit the requirements of the load.

The automatic cut off engine is also divided into two classes. First, the single valve, in which the point of cut off is varied by changing the amount of travel of the valve, and second, the four valve engines, in which the cut off is usually effected by a detaching mechanism or trip, under control of the governor. Most of the single valve engines are high speed, self-contained with shaft governors, and their advantages are as follows:—High rotative speeds, light weight, compactness, portability and simplicity. The term high speed, is applied to those engines in which the length of the stroke in proportion to the diameter of the cylinder is shortened, and the piston speed made up by increasing the number of revolutions, while the Corliss and the four valve detachable cut off, as well as the old fashioned slide valve engine are slow speed. A single valve engine is one in which a single valve controls the admission and distribution of steam for both ends of the cylinder, as in the Armington & Sims and the old fashioned slide valve engines. A four valve engine is one having a separate steam and exhaust valve for each end of the cylinder, as a Corliss engine, and is accomplished by attaching the valve rods to a wrist plate in connection with the eccentric rod. The motion of the exhaust valves is positive, opening and closing directly from the wrist plate. The crank of the steam valve stems is detachably connected with the wrist plate by a releasing mechanism under the control of the governor. The steam valve is closed after the mechanism is released by a vacuum dash pot connected to the other arm of the crank.

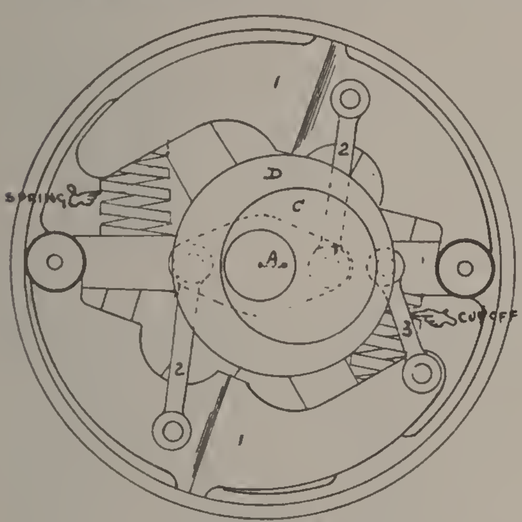
The engine that I will explain to you to-night is a single valve double ported with automatic cut off governor. The steam chest with valve seat is in one casting with the cylinder. The valve chest is enclosed by a cover as usual. This is a very desirable feature; as it enables the boring for the valve, and squaring up the ports to be accurately done, and it also gives the engineer the opportunity to set the valve easily, should it be necessary. It will be seen that the steam chest is filled with live steam, which surrounds the valve and by taking steam in the center of the valve and exhausting at each end, the steam ports from the cylinder can be very direct and the waste room kept as small as desired. In Fig. 2 the valve is shown as just taking steam into the cyl-



CYLINDER AND VALVE
FIG 2

inder port at the piston end. The port in the valve at the other end is also just taking steam into a port which passes through the valve into the same cylinder port. This enables the cylinder to take steam very quickly at the commencement of the stroke. The steam is exhausted at each end of the valve by very direct passages, which quickly free the cylinder preventing back pressure very materially.

The valve is a hollow piston valve cast in one piece, and is accurately ground, perfectly balanced, and was adopted after trial of a great many valves of different types for the following reasons: It is balanced, it is simple, there is nothing to get out of order and put undue labor on the regulator. It takes double the quantity of steam, as the usual piston valve gives a quick admission of steam and high economy with a small amount of clearance. This valve has been in use now for five years or more, and is perfectly tight. In fact, if properly made, and the lubrication attended to, they will keep tight much longer, and they are much more easily replaced or repaired than valves of any other type. The regulator or governor is what is known as the pulley governor, by which the valve operating eccentric is moved relative to the shaft by centrifugally acting weights, so as to vary the throw of the valve and thus govern the admission of steam to the cylinder to control the engine. Fig. 3 consists of a wheel which is fixed to the engine shaft and to which are hinged the weights 1—1. These weights are controlled by springs, one end of which are fixed to the rim of the pulley, and the other in a pocket cast in the weight. The main eccentric C having ears attached, is placed on the hub plate, which is bolted to the hub of the driving pulley and is free to move on the hub plate. From these ears, there are two links 2—2, which are connected to the weights 1—1. On the outside of the main eccentric and free to turn is placed an eccentric ring D, from which the cut off link 3 is attached to the toe of one of the weights. On the eccentric ring are placed the usual eccentric straps, which has been omitted for clearness, to which are directly attached the valve rod.



GOVERNOR SHOWING LEAD OR SHORTEST POINT OF CUTOFF.

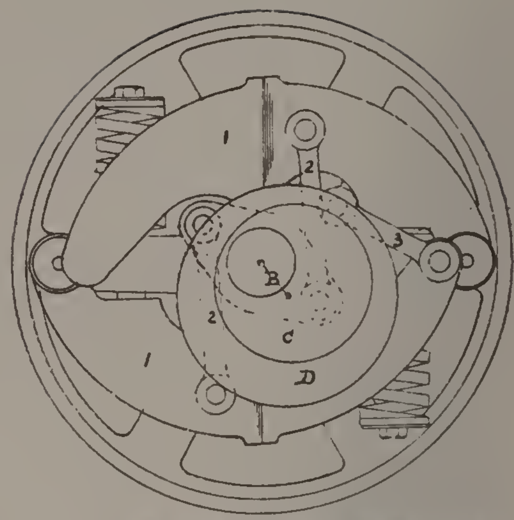
Fig. 3

It will be seen that when the engine is running at its greatest velocity, the weights due to the centrifugal force overcoming the tension of the springs will be out.

The positions of the eccentrics will then be as shown in Fig. 3 *A*, which gives the valve its least travel and its shortest cut off.

We will now take the other extreme. When the engine has its greatest load, requiring later cut off, the position of the eccentric will

then be as Fig. 4 B. It will be seen that when the weights are in this position, the main eccentric C. has been moved back ; and the eccentric ring D. has been moved forward, or in the opposite direction, and the eccentricity of this combined movement is increased B, sufficient to allow the steam to follow the piston up to the proper point of cut off. It is this wide range from the simple lead of the valve *A* Fig. 3 that causes the extreme sensitiveness of the governor and obtains such close and quick regulation. A feature peculiar to this governor is that it acts instantaneously, and whatever the change in load or steam pressure, the variation in speed from an extreme light load to the capacity of the engine will not exceed over two per cent.



GOVERNOR SHOWING FULL POINT OF CUT OFF

FIG 4

The instant there is the least variation of load or steam pressure, it is met by the governor and controlled ; and there can be no more severe test of the governing power of an engine than the Electric Light.

BACK PRESSURE.

Back Pressure has considerable influence on the total work done by a given weight of steam. Suppose the piston of a steam engine to be acted upon on one side by steam of 45 lbs. pressure absolute ; and if it be possible, let there be no pressure acting on the other side of the piston. Then if the pressure of the steam were maintained uniform through the stroke, the diagram of pressures end volumes, or in other words, the diagram of work would be a simple rectangle Fig. 5. But in ordinary engines without a condenser, as the Locomotive and Factory engines, when the steam acts on one side of the piston, communication is open with the atmosphere through the exhaust passage on the other side, and it is therefore exposed to a back pressure of 15 lbs. per square inch, Fig. 6. The effective pressure is therefore 45—15 or 30 lbs ; and the effect is to remove all the lower part from zero to 15 lbs., and thus reduce the area of the diagram and also the effective work done. In practice there is an additional back pressure of from 2 to 4 lbs, possibly due to incompleteness of exhaust, making a total back pressure of from 17 to 19 lbs. per square inch. It is much more than this at high piston speeds.

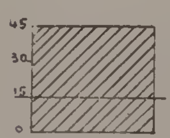


FIG 5

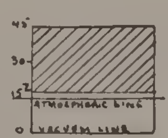


FIG 6

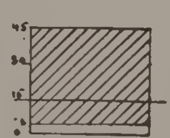


FIG 7

If, however, the cylinder during exhaust were put into communication with a condenser, then a large portion of the atmosphere is removed, and a back pressure of not more than 3 or 4 pounds absolute will now oppose the motion of the piston.

In this case, the area of the diagram representing the effective work done, will extend down to within 3 pounds of the zero limit, Fig. 7; the gain of work being proportional to the gain of area, while the weight of steam is the same. The effective pressure equals the difference between pressures on each side of the piston.

Steam is water in a gaseous condition, and when steam is cooled, it again returns to a liquid state and becomes water. Thus let a flask, *A*, contain a pound of water and fit a cork and glass tube to it as shown. Fig. 8, and connect it with a spiral tube surrounded by flowing cold water. Let the lower end of the tube pass into a vessel B. Boil the water in *A*, and it will pass off as steam by the tube *C.* to the spiral. Now the spiral or condensing tube being surrounded by cold water, it will extract a certain number of heat units from the steam, thereby condensing the steam into water, which will drop from the end of the tube. At the end of the operation, the loss of weight by *A*, is equal to the gain by *B.*, minus the small amount of impurities left in *A*. This illustrates the process of distillation, and by this method pure water may be obtained from water containing impurities.

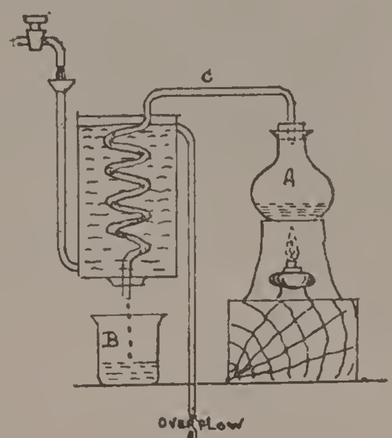


FIG 8

Advantage was taken by the early engineers of this property of easy condensation, possessed by steam. They valued the steam not so much for its own sake, but because by condensation, they were able to utilize the pressure of the atmosphere in the performance of the work.

A vacuum is literally an empty space, absolutely free from air or vapor of any kind, capable of exerting pressure. Vapor arises from water at all temperatures, and the lowness to which the pressure can be reduced, depends on the temperature of the condensed steam; and this temperature in practice cannot economically be reduced below 102 degrees Fah., at which temperature the vapor of water exerts a pressure of one pound per square inch. The condensed steam vapor and air in condensers is removed by an air pump, and shown in Fig. 9. Now when the plunger *A.* is lifted, the valve *B.* will lift by virtue of the difference in pressure on the two sides of the valve.

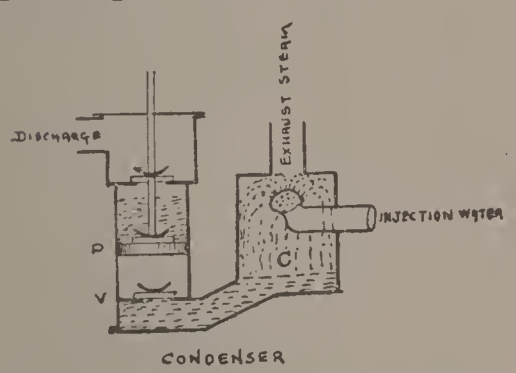


FIG 9

Assuming that we could obtain a perfect vacuum in the pump chamber, yet the pressure per square inch in the condenser *C.* can never fall below that necessary to lift the valve, *V*.

The secret of economy is in carrying out the principal as laid down by Watt, namely that the cylinder should be kept as hot as the steam that enters it; and engineers from Watt's day to the present have striven to accomplish this result.

INCANDESCENT LAMPS AND THEIR MANUFACTURE,

BY

JOHN W. HOWELL,

ASSISTANT MANAGER OF EDISON LAMP WORKS.

The light giving body in an incandescent lamp is a carbon filament heated to white heat by a current of electricity.

White hot carbon is the source of light in nearly all artificial illuminants.

The light of a gas flame comes from white hot molecules of carbon which are in the gas and which are heated to incandescence by the burning gas. Candles and oil lamps are complete gas making plants, the heat of the flame evaporates the melted wax or oil producing a constant supply of vapor or gas which is burned as fast as it is produced.

Air is present in all these gas flames and the carbon molecules are consumed. If the air supply be insufficient, the carbon will not be entirely consumed and some of it will be set free in the air in the form of soot, which you have all seen on smoky lamp chimmeys.

In the incandescent lamp as in the candle the source of light is the white hot carbon, the difference being; the sources of heat, electricity in one case and the combustion of gas in the other; and the permanence of the carbon in one case and its destruction in the other.

The stability of the carbon filament at white heat in an incandescent lamp is the measure of its value, and to secure it is the problem which lamp makers have worked upon for fifteen years and which is still before them. This problem embodies a number of separate problems and as each of these approaches solution the main problem is modified by increasing the degree of heat at which the carbon is operated.

The four elements of an incandescent lamp are, the glass enclosing chambers, the carbon filament, the vacuum, and the connections between the carbon filament and the electric circuit. Each of these elements presents difficult problems to the lamp maker, and I do not hesitate to say that lamps as made to-day are capable of improvement in each one of these elements.

The difficulty in making an incandescent lamp lies in the intimate association of these four elements and the impossibility of separating them for separate investigation. A defect which recently appeared in a new type of lamp was ascribed first to the vacuum, then to the glass chamber, then to the connections between filament and circuit, and it was only after the trouble had been definitely located in the mechanical construction of the filament itself that the other elements were relieved from suspicion.

The difficulty of ascertaining the cause of any defect in lamps necessitates the strictest adherence to routine methods of manufacture.

Slight changes in methods may produce most remarkable results and are made with the greatest caution.

The most interesting points in lamp making are, making the filaments and exhausting the lamps, nearly all filaments are made with a cellulose or silk base and are finished by treatment in hydrocarbon gas. Bamboo has been very extensively used in this country on account of its adaptability to being cut into uniform thin strips. Silk thread has also been successfully used. Cotton or paper wholly or partially dissolved and made into parchment like threads is now very generally used as the base of filaments, the advantages of this base are its cheapness and adaptability to being made into the forms desired.

The cellulose threads are wound on forms to give them the desired shapes and are carbonized by heating them to a white heat in a retort sealed up so no air can reach the inside. This process does not add carbon to the thread, it simply changes the form of carbon already in it and drives off the volatile substances which were associated with it. The carbon filaments thus made retain the form of the threads but are much smaller and weigh much less. They are nearly pure carbon, are hard and elastic and where broken look like very hard anthracite coal.

Before being used these filaments are "flashed" by heating them to high incandescence in hydrocarbon gas, this deposits hard dense gray carbon on them which renders them more stable and by stopping the "flashing" at the right time, the filaments are made of quite uniform resistance.

The filaments are mounted on short flanged tubes which are inserted in the bulbs, the flange being fused in the open end of the bulb thus bringing the filament in its proper place in the bulb.

The lamps are exhausted through small tubes sealed on their large ends, these tubes are attached to the vacuum pumps by rubber packing. The vacuum pump is a vertical straight glass tube about one-tenth of an inch bore and three feet long with a larger tube attached to its top, the lamp is attached to the larger tube. A small stream of mercury falls down the larger tube and as it enters the small tube it traps the air and

carries it down the tube with it, at first large quantities of air are carried down. As the exhaustion proceeds the air bubbles going down the tube get smaller and smaller and finally becomes invisible the tube being then filled solid with mercury. Current is now applied to the filament and the heat sets free gases from the interior parts of the lamp, bubbles immediately show again in the pump tube and the application of current is continued until the bubbles are no longer visible with the filament heated above its normal incandescence. The lamps are then sealed off by fusing off the glass tube close to the top of the bulb.

After exhaustion the lamps are rigidly inspected for all defects. They are photometered to determine what circuit each one is adapted to and then based to suit the sockets of the customer ordering them.

Before shipment, they are again rigidly inspected. They are put on racks and burned, first low to pick out spotted filaments which show better at low than at high heat; and then at normal incandescence to detect differences due to bad photometer work. They are inspected for poor vacuum by the induction coils which indicates quite accurately the character of the vacuum. After this inspection they are packed for shipment.

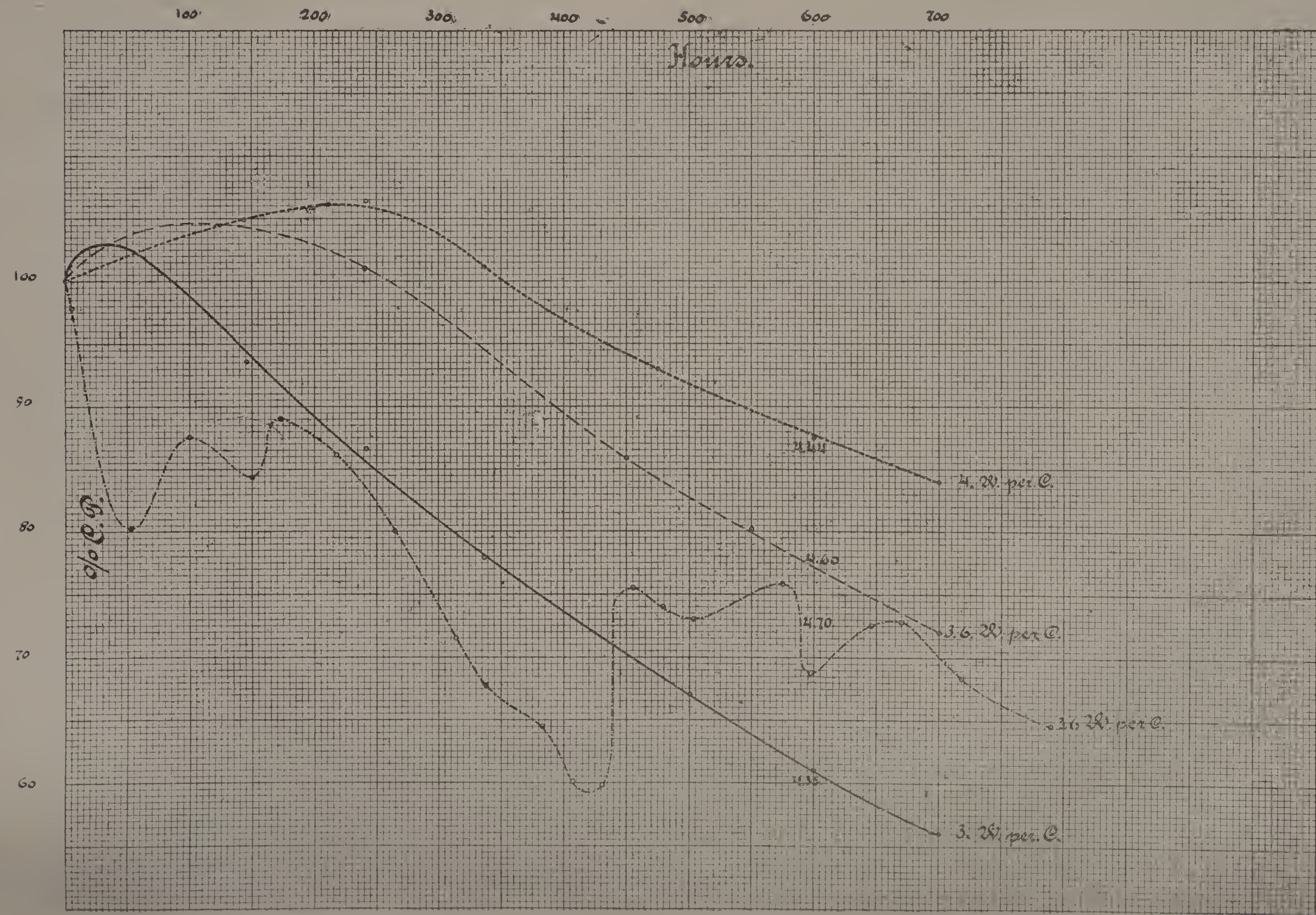
The performance of lamps both as to life and uniformity of candle power depends upon the temperature at which the filament is burned. The higher the temperature at which a filament is operated the more light it gives and the less current is required per candle of light. But while the economy of operation is increasing, the stability of the filament is decreasing.

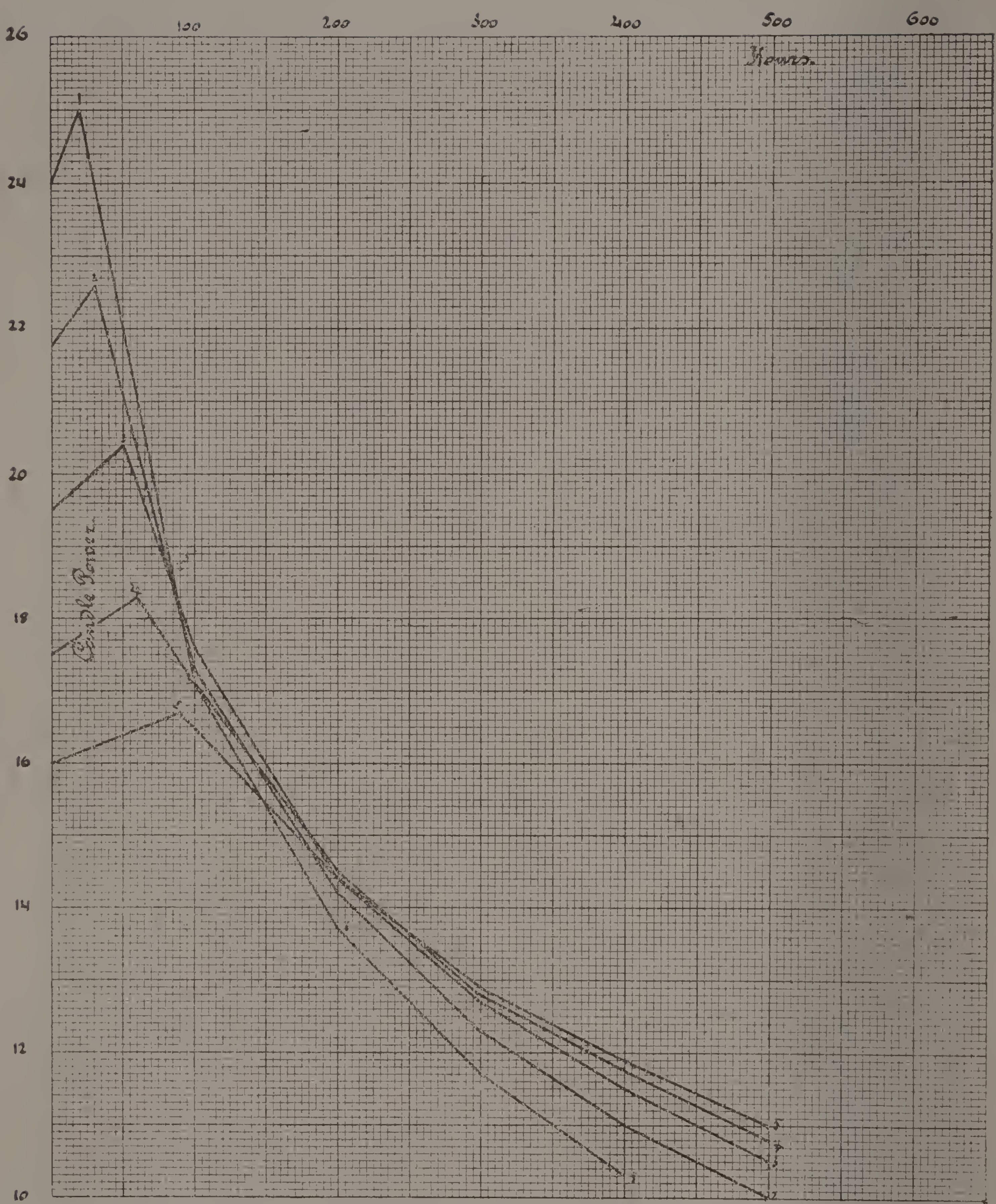
Carbon filaments are fusible, before they reach the fusing point the carbon softens. As the carbon reaches the softening condition, indicating an approach to the point of fusion, its molecules detach themselves more easily and fly to the globe in greater numbers, causing rapid blacking. The slightest weakness in the filament causes a strain which very soon breaks the filament at that point by raising the temperature there higher than the rest of the filament.

To operate high efficiency lamps, requires a very steady current as an accidental rise in the pressure may bring the filaments dangerously near the point of fusion.

The temperature of a filament is indicated by the power required to produce a candle of light, lamps are commonly made to give one candle for from three to four watts. Three watt lamps are operated at a very high temperature, they should be used only where power and conductors are expensive and where the current is very steady. Four watt lamps are much more stable, they blacken very slowly and maintain a much more constant candle power. Their useful life is about four times as long as the three watt lamps and they are not so seriously affected by irregularities of current. The chart shows the relative stabilities of the three, three and one-half and four watt lamps.

The irregular curve plotted on this chart shows the performance of the Edison lamps tested at the Franklin Institute Electrical Exhibition in 1884. A comparison of this curve and the curve of 3.6 watt lamps shows the advance made in lamps in the last ten years.


Hours.
100
200
300
400
500
600
700
% C.P.
100
90
80
70
60
4.44
4. W. per C.
4.60
3.6. W. per C.
4.70
3.6. W. per C.
4.38
3. W. per C.



100
200
300
400
500
600
Hours.
26
24
22
20
18
16
14
12
10
Candle Power.

The second chart shows the performance of 3 watt lamps operated at normal pressure and at higher pressures.

The effect of operating lamps two, four, six or eight volts above normal is to make the lamps much brighter at first, but they actually give less light after two hundred hours than the lamps operated at normal pressure. This makes a great difference between new and old lamps and shortens the useful life of lamps very materially.

Nearly all lamps increase in candle power at first and fall more or less rapidly afterward, this first increase is due to the improvement of the vacuum as the lamp is burned, new lamps have a little gas in the bulbs which is slowly absorbed by the warm glass. While the gas is present it cools the filament by conduction. As the gas is absorbed the conduction is less, the filament gets hotter and gives more light. The later fall in candle power had several causes. The molecules of carbon which are thrown from the white hot, semi-soft filament darken the glass and obscure the light. Another cause is the increased resistance of the filament which diminishes the current and consequently cools the filament just as lowering the pressure will cool it.

Another cause is the change in the surface of the filament which makes it a better radiator of heat. This cools the filament by allowing heat to radiate from the filament which previously was retained in it. The *cooling* of the filament from these causes is the chief cause of its loss of candle power. This cooling also preserves the life of the filament. If three watt filaments did not lose candle power and cool off, but were kept at the high temperature at which they were started, they would not last nearly as long as they do. Consequently, we expect any improvement which gives the lamp a better candle power curve, to shorten its life unless the stability of the carbon is correspondingly improved.

"ELECTRICAL DISTRIBUTION"

BY

WM. C. L. EGLIN,

CHIEF OF ELECTRICAL DEPARTMENT.

Although I have not the pleasure of presenting to you such a fascinating subject as we had the pleasure of listening to on last Friday evening, nevertheless it is very important that we should have a clear understanding of the methods of distribution of Electrical Energy and of the various apparatus that utilize it.

Our principal difficulty in mastering the actions of Electrical Energy is due to the fact that we do not possess an electrical sense. We can all tell the difference between heat and cold and a push or a pull ; but no one can tell either by touch or sight the difference between a positive or negative current of electricity, except by the effects they produce on other objects. Few of us realize that most of our knowledge has been gained by practical experiments. How did you find whether iron or wood was the heaviest? By lifting each or by balancing in scales. Numerous examples could be taken from every-day life.

The same is also true about Electricity, and you will never learn much about it until you make a number of simple experiments ; and for this reason, I will endeavor to demonstrate to you this evening by practical examples some of the various methods used to distribute and utilize Electrical Energy.

The simplest form of transmitting Electrical Energy is from a storage battery. The energy is stored in the battery and carried to the point of distribution.

The attempt has been made to distribute electricity by means of storage batteries, located in the consumers premises. The batteries were charged at a Central Station, and afterwards delivered to consumers by means of wagons, and served like the other necessaries of life. There

are many practical objections to this method, particularly the amount of handling that is necessary, and the expense of collecting and afterwards distributing the batteries. The first cost for batteries is also very large, as each consumer's battery must be large enough to carry the maximum load of that individual consumer, whereas were the same number of consumers supplied from a central station, the load to be supplied by the station would be an average load, which in practice rarely exceeds 50 per cent. of the lamps connected. Storage batteries are now receiving careful attention from central station managers as an auxiliary supply. The batteries being charged during the time of light load on the station, and discharged either as an auxiliary to the dynamos carrying part of the load during the time of a short heavy load, or they may be used to carry the load during the day in stations when the day load is light or at night after the heavy load has gone off. The load diagrams of most lighting stations show a high maximum, covering a period of about an hour, as storage batteries may be discharged at a very high rate for a short time without danger; they may be used to advantage in such cases. The question of the cost of the batteries and maintenance, is the principal one in deciding whether they should be used or not. The battery must cost less than the machinery required for the same output, because the loss in the battery is about 20 per cent. of the energy supplied to it, or, in other words, you must generate 20 per cent. more electricity if you distribute by means of storage batteries as compared to direct distribution.

In transmitting energy of any kind from one point to another, there is always some loss depending on the resistance offered, this loss is made manifest in the form of heat. As an example, in a line of shafting there is a certain amount of energy lost in heating of the bearings.

If the bearings are large enough and the surface smooth, the heat from the energy lost at this point will be radiated by the metal as fast as it is produced; but if the bearing is tightened so as to form a high resistance, it will become excessively hot; or if the bearing is too small, so that the heat generated is not radiated as fast as produced, it will also become excessively hot. This is exactly what takes place in electrical transmission of energy, the only difference being that we express the loss in electrical terms. The current flowing in any conductor, squared multiplied by the resistance of the conductor represents the actual power lost.

I have on this board an example. In this piece of wire I have introduced a wire having a high electrical resistance, so that if I send a current over it, the result will be a great deal more heat generated at the point of the high resistance wire. I have also a small conductor, which when a large current is passed over it, will become red hot and then fuse.

The other example is a wire insulated likes the wires in every day use. You see that when a large amount of current is forced over this wire that the insulation immediately fires, showing you one of the dangers that must be avoided, and that the wires must be large enough to carry the current without undue heating, and be properly protected with safety fuses.

The resistance of a wire depends upon its length and inversely as its cross section, that is to say, the longer the wire the greater its resistance; and the smaller in cross section, the greater the resistance. The heat developed is equal to the current squared, multiplied by the resistance of the conductor multiplied by the time.

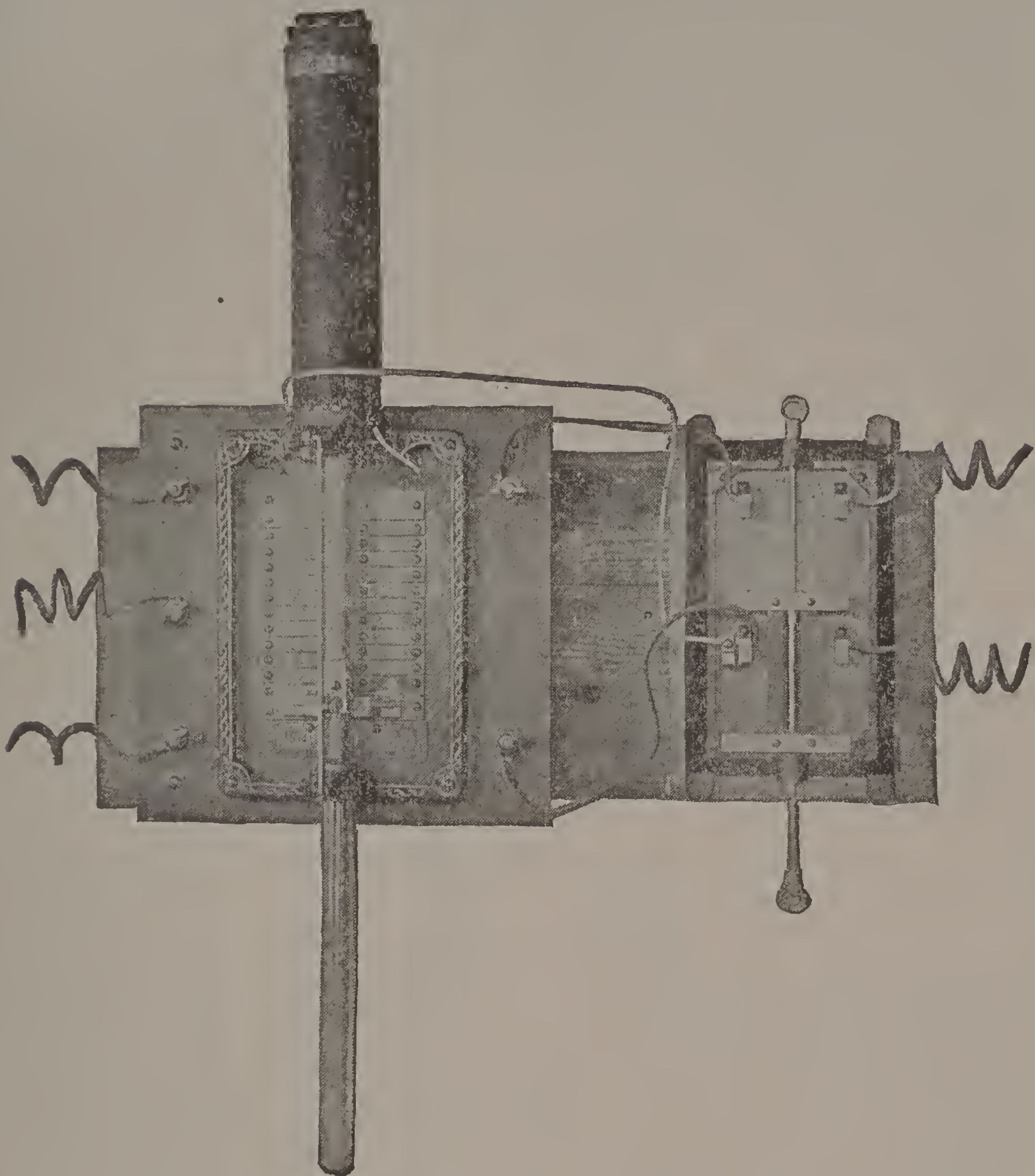
It might be supposed that a bare wire would remain cooler than a covered one, but this is not so; and the reason is that the air is a very bad conductor of heat, and although the materials used to cover wires are not good conductors of heat, they are very much better than air; and as the surface exposed by the insulation is much larger than the wire, more heat is radiated. Another form of electrical resistance is Counter Electro-Motive Force which means an electrical pressure opposing the current. The effective pressure in such a case would depend on the initial pressure minus the opposing pressure.

This form of resistance is sometimes called spurious resistance to distinguish it from ohmic or true resistance. Take as an example of this form of resistance an electric motor, and consider the effect of sending electricity through such a piece of apparatus. A motor briefly consists of an electric magnet and a few turns of wire wound on an iron core and mounted on a shaft so that it is free to move between the poles of the magnet Oeisted discovered that when a wire carrying an electric current was placed near a magnet, there was an attraction between the wire and the magnet tending to move the wire in the direction of the lines of force of the magnet. Lines of force are imaginary lines between the poles of the magnet, and are used to express the intensity of magnetism and the direction of the force. If the current is varied in the coils, the armature, as the moving part is called, so that when one coil reaches the point parallel to the lines of force, the current is reduced to zero; the armature will rotate and when the variations are made continuous by means of a commutator, the motion is continuous as long as electricity is supplied.

Lenz's law says that the direction of the currents set up by electro magnet induction, is always such as tend to oppose the motion producing them. It is the converse of the law which we apply to motors, that the motion produced is always such as tend to stop the current. When the motor is at rest there is no magneto electric induction so the current flowing would depend only on the resistance of the wire on the armature, and as this in practice is very small, the amount flowing would be excessive. Now as the motor increases in speed, the magneto electric induction increases, and as this current is an opposite direction, the current flowing through the armature is reduced. In starting a motor we must introduce an extra resistance in the armature circuit, or in other words, lengthen the wire in armature; as the speed of the armature increases, increasing the counter Electro Motive Force, the wire in the external resistance is gradually cut out until the machine has reached its working speed.

I have here a motor with a starting box, as the extra resistance is called, which is automatic in its actions, and insures the resistance always being in circuit when the armature is at rest. The advantage of using such a starting box is that the current may be turned on or off the motor from any point without giving it any further attention.

Some of the uses of this device are operating elevators, machines, pumps and other machinery which is operated at intervals and at a distance from the points of control.

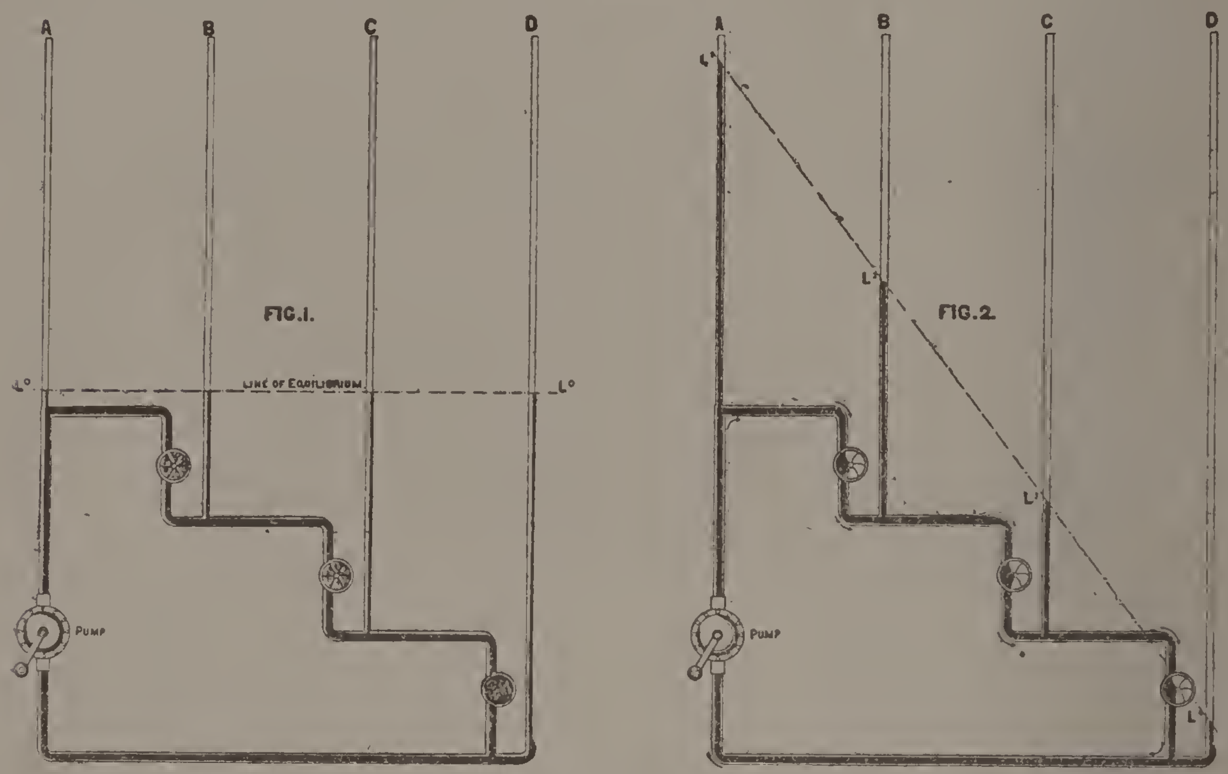


In reasoning the various electrical questions you must act very similarly as you would were you required to speak in a foreign language, in which case you would think in English and speak in the foreign tongue. So it is in electrical questions; you must compare the points under consideration to other well known means and express yourself in electrical terms, and for this reason I will compare the methods of electrical distribution of energy to water distribution of energy.

The manner in which our lamps and motors or other apparatus are connected to the dynamo may be divided into two classes, series and multiple arc or parallel. What is meant by a series connection is, that the total current flowing into the conductor passes through each piece of apparatus connected to the generator; and the amount of energy used by each piece of apparatus so connected will depend on the amount of current passed through it in Amperes multiplied by the difference in pressure in volts between the points of entering and leaving the apparatus.

In this diagram of the water analogue we have a rotary pump and three turbine wheels, which are equivalent to dynamos and motors or lamps, connected to the same pipe with vertical pipes *A. B. C. & D.*, connected to the points of entering and leaving of each wheel. You will see that as long as the pump remains stationery, these is no difference of pressure between any of the pipes connected to the inlet and outlet of the turbines. As soon as the pump is moved the water is drawn from the lower pipe and forced into the upper pipe.

SERIES WATER ANALOGUE.



The different pressures then between the various turbines is shown by the line *L.* 1., *L.* 2., *L.* 4. You will see that in this method that the total difference in pressure *L.* 1. to *L.* 4. is the pressure required to force the water against the combined resistance of all the turbines.

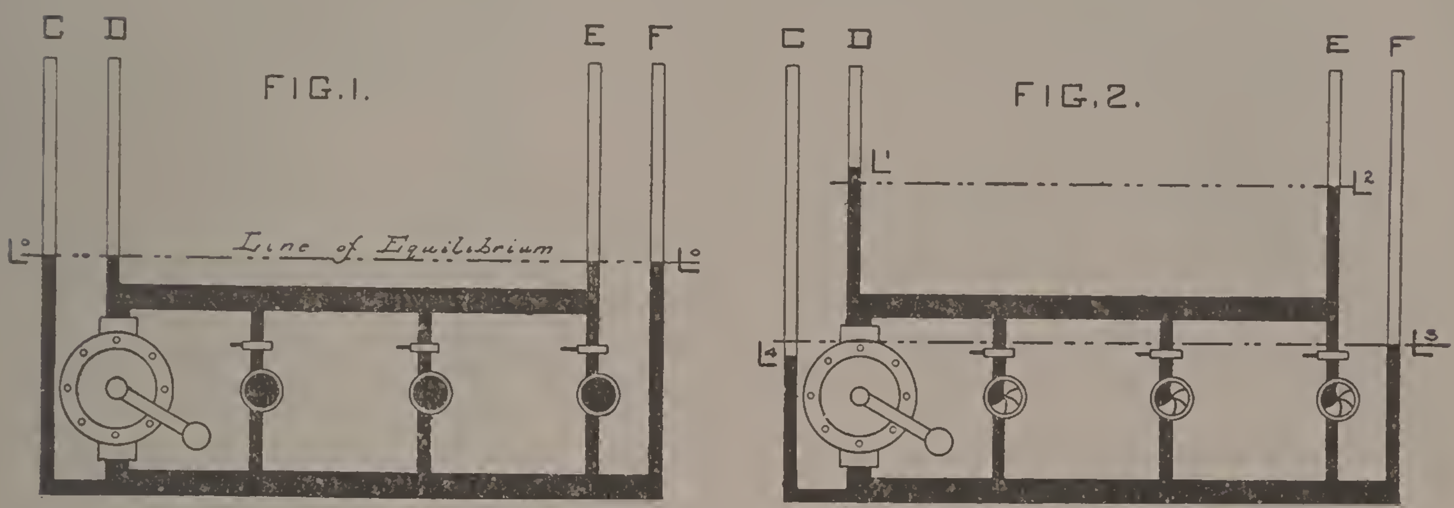
In apparatus connected in multiple arc or parallel only part of the current passes through each piece of apparatus and the pressure remains constant, or in other words, the current is split up in proportions depending on the resistance of the various pieces of apparatus so connected. I use the word "apparatus" because the same systems are applicable to incandescent lamps, arc lamps, motors or miscellaneous instruments.

Referring to diagram No. 2, showing the multiple arc water analogue. In the first figure the pump is at rest and each turbine wheel has an independent connection to the pump. The two tubes *H.* and *G.* are connected to the lower or return and the tubes *E.* and *L.* to the upper or pressure pipe. As long as the pump is stationary, there is no difference of pressure in the upper or lower pipes.

In figure 2 we have the conditions with pump in action. The pressure in the pipe *H*, is the lowest, and the difference in level between *H* and *G* is the amount lost in the return pipe. The difference in level between *E* and *F* is the amount lost in the outgoing pipe. The difference

in pressure between $L2$ and $L3$ is the actual working pressure of the last turbine. You will see that shutting off one or more of these turbines does not prevent the others from running, the only effect it produces is to lessen the difference of pressure between $L1$ and $L2$, and $L3$ and $L4$, or in other words, reduces the loss in transmission.

MULTIPLE-ARC WATER ANALOGUE



These two methods, series and parallel, are arranged in many combinations which readily present themselves when occasion arises.

You would probably ask, what is the use of the series system and what are its advantages, as compared with the parallel system? The advantages of connecting in series is that the size of the conductor remains the same, independent of the number of lamps or other apparatus attached. That is, the wire should be made large enough to carry one lamp and the pressure increased for each additional lamp added. The limit to the number of lamps connected in series depends only on the safe electrical pressure, which is rather a disputed point; about 2000 volts is the highest used in general practice. There have been one or two cases in which much higher voltages have been used.

The principal reason for the use of series connection is on account of its cheapness. You can easily see that it is by far the simplest and cheapest method to convey the energy from the point of supply to the apparatus. The disadvantages, however, in many cases more than counter-balance the advantages.

When pressures of over 500 or 600 volts are used, they are dangerous to persons and animals. I am sorry to say, however, that danger to life is not considered very seriously by many people, so that other objections must be found. The real fault in this system is, that if at any point in the chain of connections there is a break, the whole system fails.

I have in my hand 8 lamps connected in series. As each requires only a low Electro Motive Force, the total Electro Motive Force is not dangerous, being only 110 volts. You will see as I turn one lamp off, the other seven also go out.

A number of methods have been devised for completing the circuit in the event of the carbon in the incandescent lamp breaking. It has been found, however, that there are many difficulties of a practical

nature that arise in a series system of incandescent lighting, and to-day they are rapidly going out of use.

In arc lighting the problem is much simpler, as the current is greater and a slight increase in pressure, due to one or two lamps being cut out, has little effect on the others. The dynamos for series working arc lamps are usually self regulating, so that they respond quickly to the difference in resistance of the outside circuit or load.

In the parallel system of connections, each lamp is practically independent and the main conductor must be increased in cross section for each additional lamp added. By this method you have perfect control of each lamp.

In the parallel arrangement the current is increased for each additional piece of apparatus connected. Now as we add on the lamps or motors, you will see our currents become very great. The loss in conveying electricity from one point to another, as we have already seen, depends on the current squared multiplied by the resistance of the conductor, so that in parallel distribution the resistance of the conductor must be small, or in other words we must use a large conductor.

The Edison three-wire system of distribution is a combination of a series and multiple arc arrangement, and possesses the decided advantage that the same number of lamps may be supplied with ⅜ of the weight of copper required by the two-wire multiple arc method; and it also possesses all the advantages regarding control of each light independently, and it it is free from danger to life, as the greatest difference of pressure in any part of the system is only about 230 volts.

In the diagram 3, we have the water analogue, there are two pumps so arranged that the water from the one discharges into the other or raises the pressure of the second pump's supply, thus increasing the pressure of combined arrangement to the sum of these separate pressures.

Connected to the supply and discharge pipe of each pump are turbine wheels. The pipes $A\ C\ D$ and $F\ E\ H$, are pressure tubes. Fig. 1 the pumps are at rest, and the water level the same in each pipe, so that there is no motion of the turbine wheels.

Fig. 2. The pumps are in operation. The difference of levels, $L1$ and $L3$ is the same as $L2$ and $L5$, so that the turbine wheels between these levels will revolve. The current, however, does return directly to the pump supplying it, as there is still a difference of pressure between the discharge end of the upper turbine and the discharge end of the lower turbine, this water will flow through the lower turbine and operate it, so that the same current operates both turbines. If, however, one of the wheels is shut off in either the upper or lower set; or in other words, if they are unbalanced, the difference in balance is supplied by the middle pipe. The difference in levels $L1$ and $L2$ and $L5$ and $L6$ is the pressure lost in transmission.

The point which must receive attention in the three-wire system, is the balancing must be as nearly uniform as possible, and the connection of the middle or neutral wire must not be broken before the outside wires. Should the middle or neutral wire, as it is called, be broken and the lamps

3-WIRE SYSTEM WATER ANALOGUE.

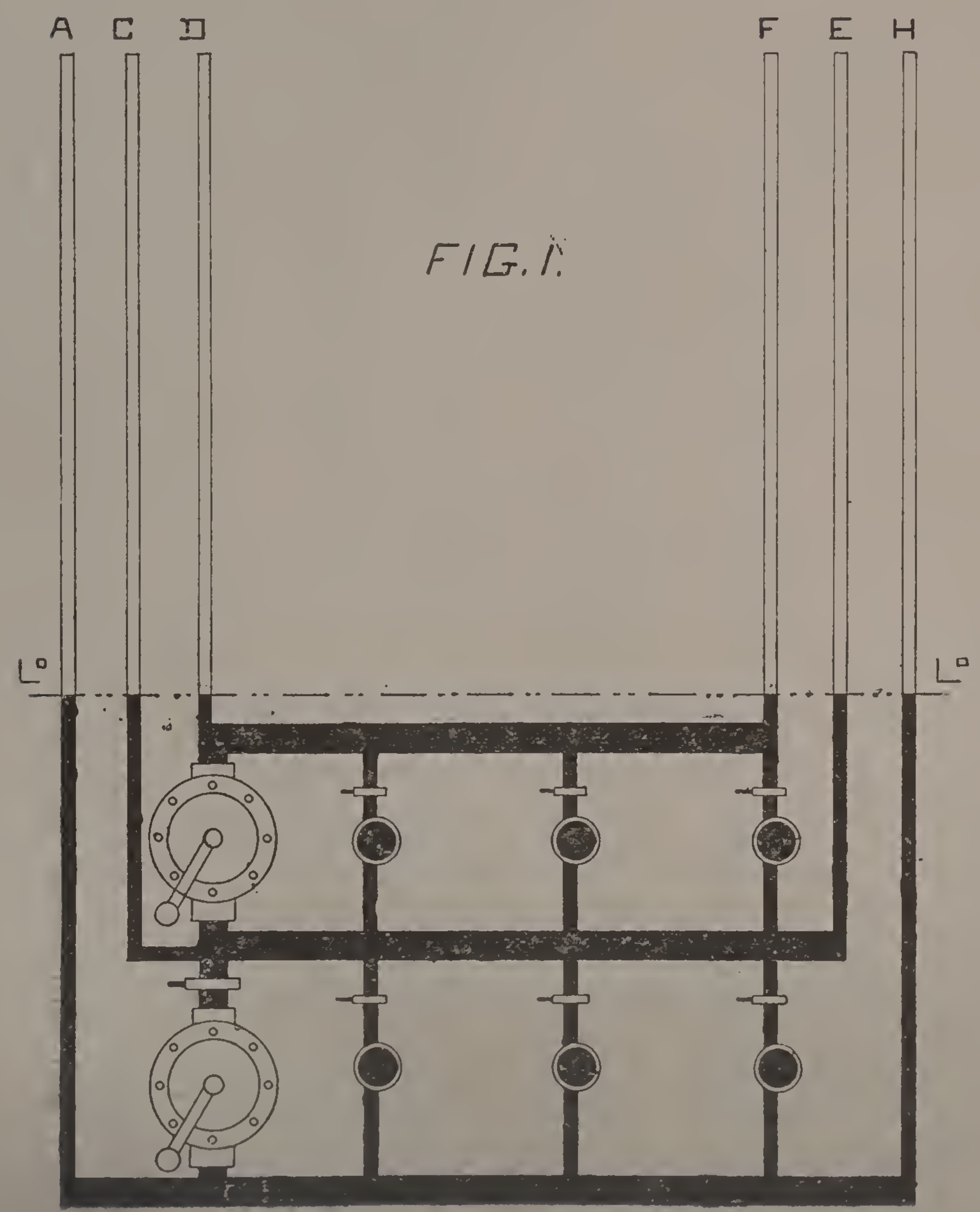


FIG. 1.

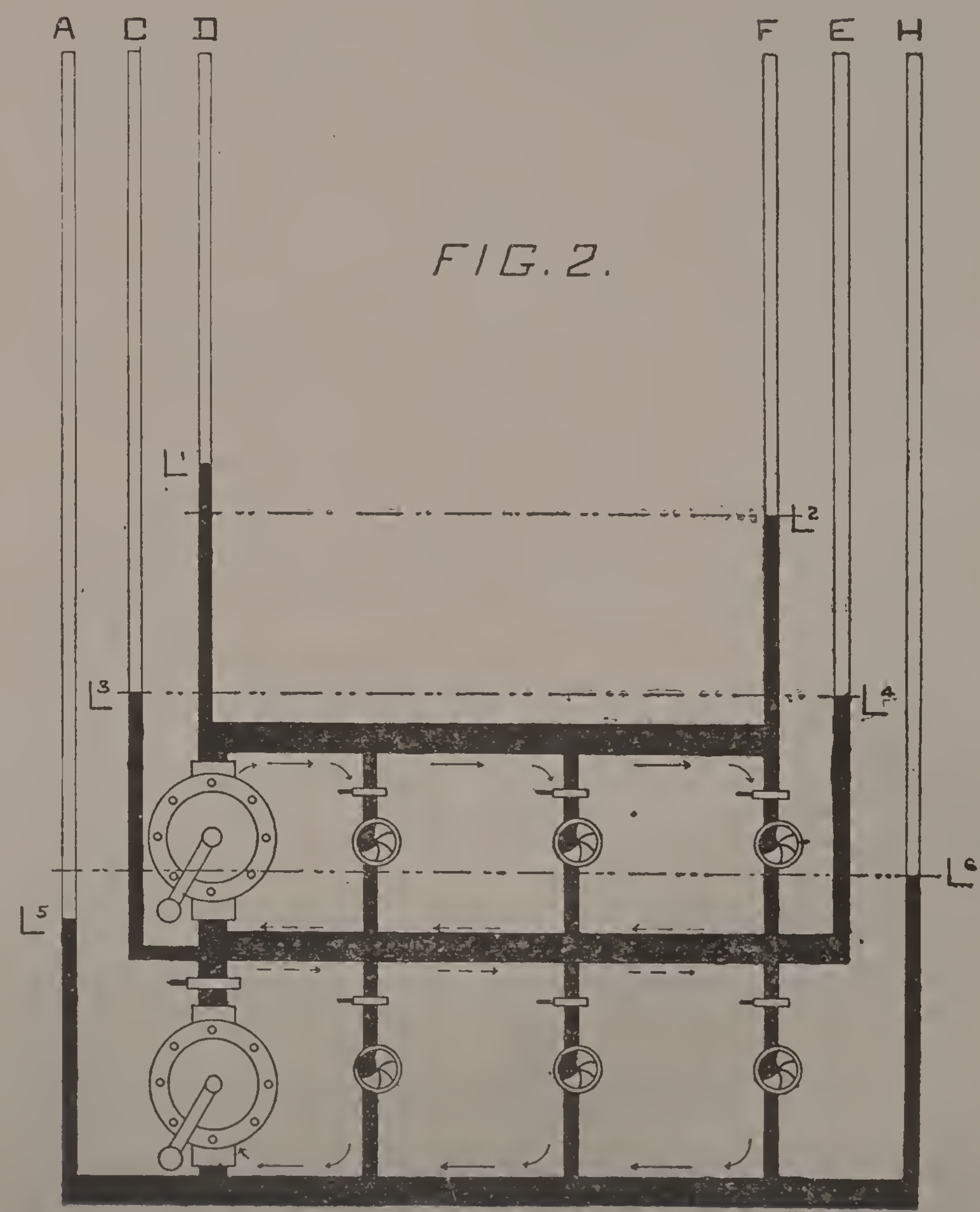


FIG. 2.

be unevenly balanced between the two outside wires, the current from the greater number of lamps would be forced through the smaller, making the current greater in the smaller number of lamps and destroying the filaments. This is avoided in practice by making the neutral fuse twice the size of either of the outside wires.

Diagrams 4 show the losses in lamps arranged on the two-wire or three-wire system.

Since we know that the loss in transmission depends on the current squared multiplied by the resistance of the conductor, by referring to the diagram we see that the current required to supply 10 lamps arranged on the three-wire system is half that required by the two-wire system. The loss would be one-quarter in the three wire system compared to the two-wire.

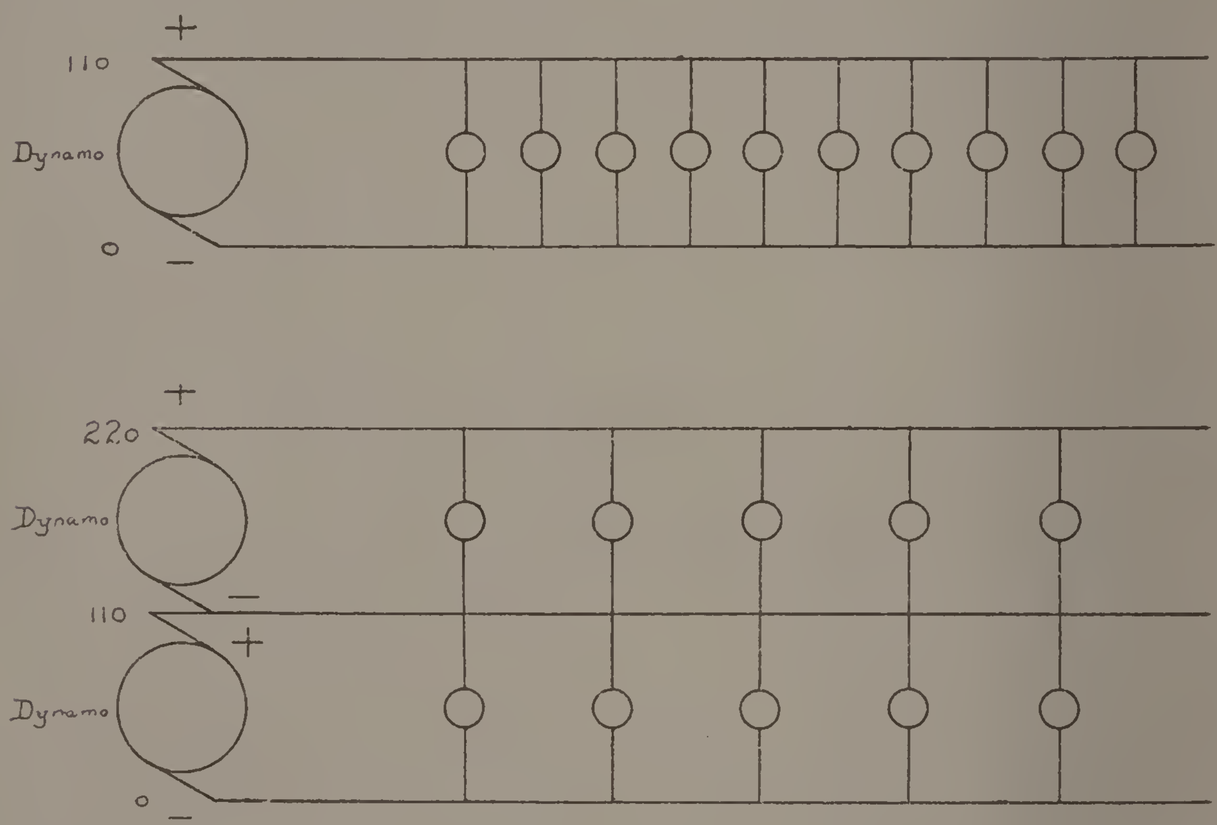
Example 10 lamps each requiring one ampere of current.

Loss two wire system, 10 squared $\times$ R = 100 $\times$ R.

Loss three wire system, 5 squared $\times$ R = 25 $\times$ R.

R equals resistance of conductor.

As three wires of ¼ the cross section are to be compared to two wires. The total cross section is ⅜ of the two-wire system.



BOILER FEED APPARATUS FOR ELECTRIC LIGHT STATIONS.

BY

WILLIAM. M. BARR,

CONSULTING ENGINEER.

In the paper which I shall read to you this evening on the mechanism for feeding steam boilers, I shall not enter upon a historical sketch of the subject, but shall confine myself to the description of the modern steam pump, corresponding as nearly as possible to just such a machine as you will be called upon to use in your daily round of duty.

The site for a power station having been selected, the H. P. of the boilers having also been determined upon, the quantity of water required for evaporation, and for other purposes ; is easily arrived at. In round numbers one cubic foot of water supply is commonly provided for each I. H. P. for such steam plants as do not employ very large engines of the compound or triple expansion type. An ordinary high-speed, direct-coupled engine, fitted with either a flat slide valve or a piston valve for steam distribution, the valve driven and controlled by a shaft governor will require at a fair average 30 pounds of water for each indicated horse power per hour.

As a cubic foot of water weighs 62¼ pounds there is left an apparent surplus of a little more than ½ the water allowance, part of which is to be applied to operating the boiler feed pumps and to make good unavoidable waste.

It will be seen that under all ordinary conditions the water allowance is ample, even under what might be considered disadvantageous ones.

A water supply of good quality is a desirable adjunct to any steam plant, it rarely happens, however, that a steam plant can be made to accommodate itself in the matter of location to that of water supply, nor is this very important except in those cases in which condensing engines are

employed ; such a location may, perhaps, be secured in a suburban station, but not within city limits, so that recourse must be had to a surface well, or perhaps a bored well, commonly called an artesian well, in case the ordinary hydrant or city water is not to be used. If a surface well is employed the water level is usually within the limits of suction, in which case a boiler feed pump can be used to lift its own water as well as force it into the boiler.

In the case of deeper surface wells, and for bored wells, a separate lift pump is commonly used specially adapted for deep well pumping, the delivery being into a tank, which may, for greater convenience in fire protection, be placed above the roof of the building, an arrangement which serves an equally useful purpose when cleaning out the boilers. The boiler feed pump can receive its supply from this overhead tank, but a better arrangement is to have a small cistern near the pump, below the engine or boiler room floor. This cistern should be lined and floored with brick, and cemented water tight.

If the water supply be from a pond or stream, there should be a strainer box at the outer end of the suction pipe to keep out floating matter such as twigs, leaves, etc.

Water Analyses may be thought to be foreign to the subject in hand, but a few words by way of recommendation or advice, simply this : Water from a new well, whether a shallow well consisting largely of surface drainage, or from a bored well extending to a lower water bearing stratum, should be analyzed by a competent chemist ; the result of the analysis will have an important bearing upon the care and management of the boiler. The principal impurities in feed water are the carbonates of lime and magnesia, occasionally, however, the sulphates are in solution instead, the latter are much more difficult to deal with than the former.

Gritty water is always troublesome unless a large settling tank or pond is conveniently near, in lieu of this, a pressure filter may be used, but this is another story.

The requirements of a boiler feed pump are simply to take the water from the supply and deliver it into the boiler under pressure. The pump should be simple, easily managed, and certain in its operation. Independent steam pumps must be capable of working at varying speeds if used for other purposes than feeding steam boilers, and must, whenever required, run at a constant speed suited to the rate of evaporation going on in the boilers.

The manufacture of steam pumps is a specialized industry, the engineer has, therefore, little else than a choice of variety and size.

A plunger pump is, perhaps, oftener selected for boiler feeding than any other kind. The simplest form is a solid plunger working through a solid ring, the plunger is commonly made of cast iron, the ring of brass. The latter is made non-adjustable and centers the plunger by fitting in a bored recess in the pump chamber, this arrangement works with very little friction. Unless the water is very gritty, such a combination of plunger and ring will wear a long time, and has proven very

satisfactory. Hot and cold water can be pumped equally well, Fig. 112.

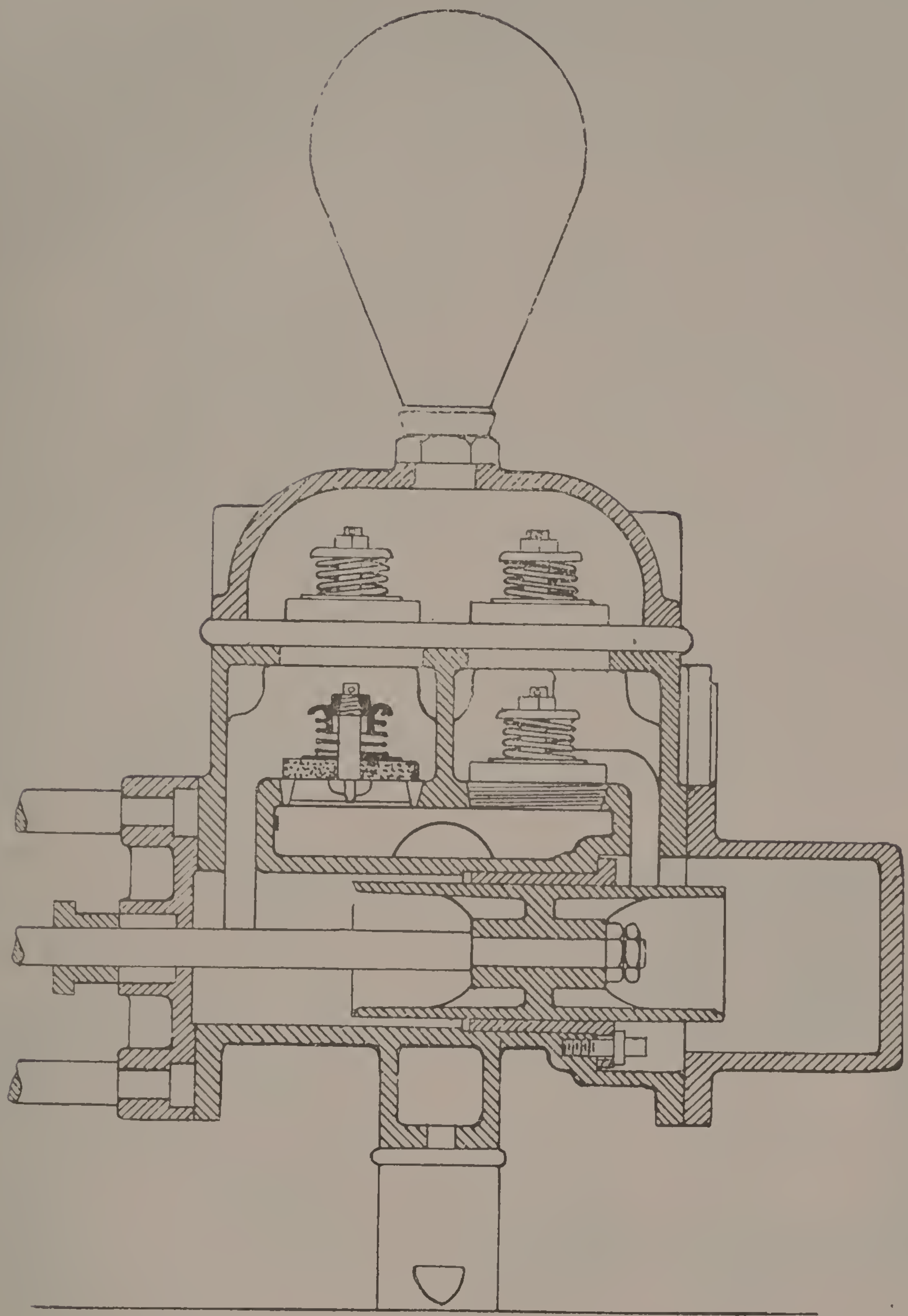


Fig. 112.

A packed plunger pump is seldom selected for a boiler feed, it posesses no advantage over the ordinary plunger and ring, unless the water contains an unusual amount of grit or mud. Packed plungers are fitted with stuffing boxes and glands adapted for fibrous packing similar to that used for steam piston rods. This arrangement is well suited for pumping cold water, but the friction is much greater than when a plain ring is used. For pumping very hot water there is always more or less trouble in keeping the stuffing boxes tight, as the packing is liable to soften under the action of the heat, but with proper care and close attention to minor leaks, the performance of such a water end can be made satisfactory. An

inside packed plunger pump is one in which the packing box is inside of the water cylinder; an outside packed plunger pump is fitted with stuffing boxes on the outside of the water end, a portion of the plunger being always exposed to the atmosphere.

Piston pumps are not so generally selected for feeding steam boilers as are plunger pumps. Small water ends are generally bushed with brass tubing pressed or driven into place and caulked tight at the ends to prevent end motion. The pistons are adapted for the use of fibrous packing, and occasionally they are fitted with metal rings, these latter are seldom satisfactory in practice, especially if the water is gritty; for pumping very hot water metal rings become almost a necessity, because of the destructive action of the hot water upon the fibrous packing.

A direct acting pump is one in which the piston rod is continuous from the steam piston to that of the plunger or piston of the water end, all three moving together as a single piece. Such pumps may be either single or duplex. When properly designed and built they are compact, efficient, durable, and sell at a very moderate price. The objection to all direct acting pumps as a class is their want of economy in the use of steam, there being no stored up energy as in the case of a fly wheel, the steam pressure must be as great at the moment of exhaust as at the beginning of the stroke, and this, as is well known to all steam engineers, is a most extravagant and wasteful method of using steam; fortunately the quantity of steam thus used is so small in proportion to that required elsewhere about the power plant that it can be spared without serious loss. Figs. 171 and 172.

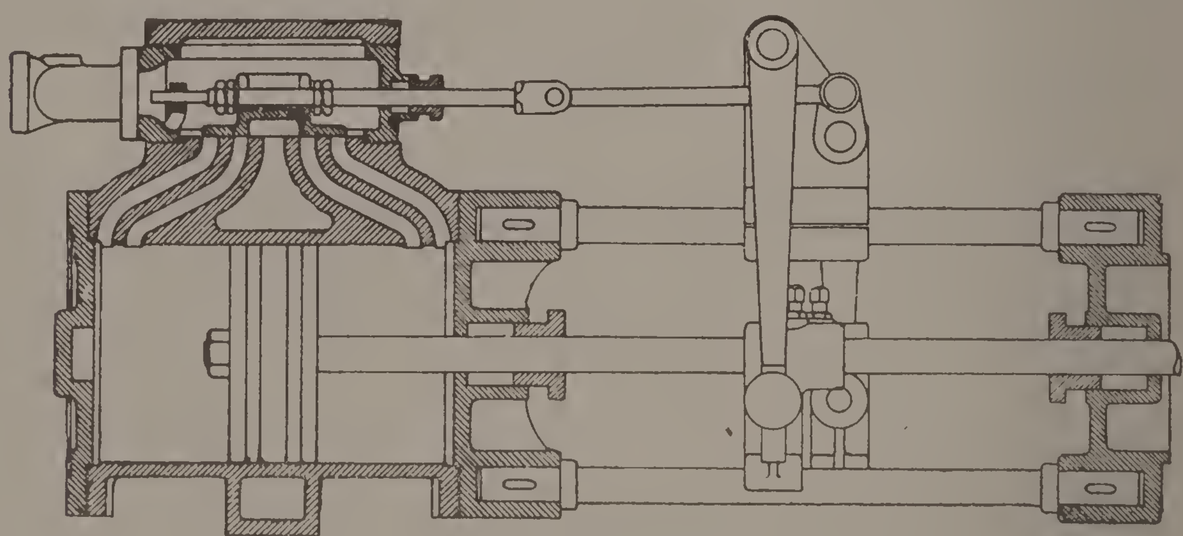


Fig. 171.

The relation of steam cylinder area to that of water plunger area varies from 2 to 1, to 3 to 1. In a direct acting pump it really makes but little difference which ratio is selected, because the steam pressure must be throttled down to that required to overcome the boiler pressure, the losses occurring within the pump itself, and the friction of the water through the pipes and valves on its way to the boiler; but, on general principles, if a 2 to 1 ratio will do the work satisfactorily there is no reason why a larger steam cylinder should be used, with its larger ports, and larger radiating surface.

The capacity of a pump is commonly rated at the number of gallons of water it will deliver per minute—the piston speed is generally assumed to be 100 per minute, it is also assumed that the pump makes its full stroke continuouly without loss. It may be a gratuitous bit of information to say to you that direct acting boiler feed pumps scarcely, if ever, run at that piston speed continuously, and as for making a full stroke, this can hardly be assumed to be true, especially in the case of duplex pumps; it will be well, therefore, when consulting a catalogue of trade pumps, especially for the smaller sizes, to scale down the rating from 30 to 50 per cent. when selecting a boiler feed pump.

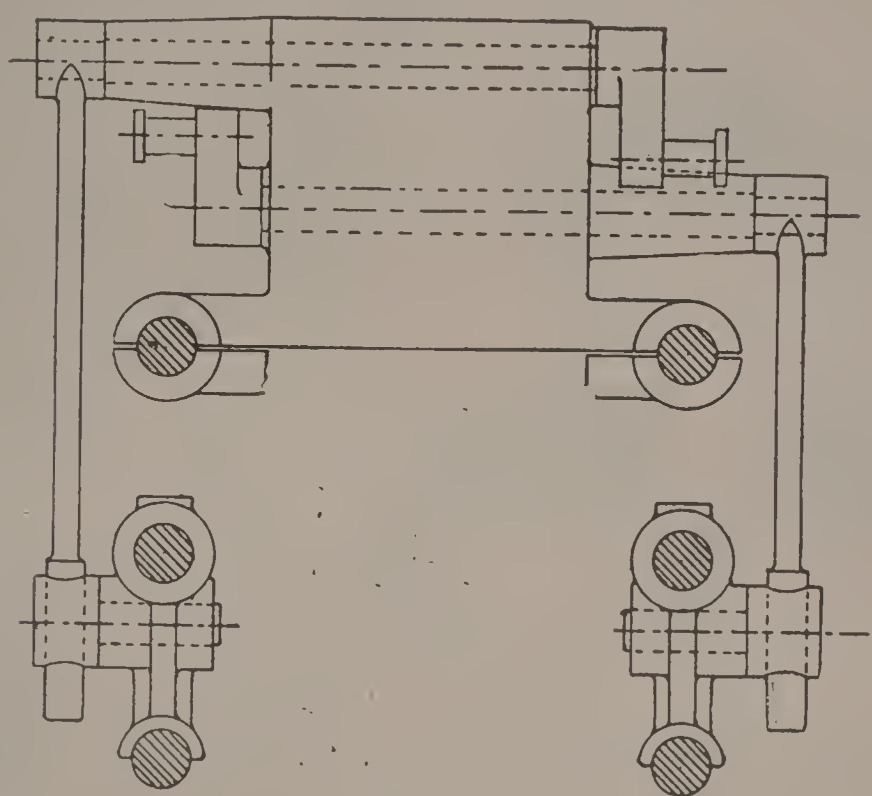


Fig. 172.

One cubic foot of fresh water equals approximately 7½ U. S. gallons of 231 cubic inches. The weight of a U. S. gallon of fresh water is 8.32 pounds. To acertain the capacity of a pump, multiply the area of the plunger in inches, by its length of stroke, also in inches, multiply the product by the number of strokes per minute, and divide by 231, which will give the displacement in gallons per minute; from this, certain deductions must be made for non-filling at each stroke, and, in the case of direct acting pumps, for the shortening up of the strokes at each end of the pump. This allowance is one which each must judge for himself but it will be found to range anywhere from 10 to 25 per cent. The speed of a boiler feed pump will, in actual practice, rarely exceed 50 feet per minute, or half the tabulated speed given in trade catalogues.

Water valves. The question of valve area is an important one, because upon it, more than anything else depends the speed at which a pump can be noiselessly run. An ordinary trade pump, such as would be selected for feeding steam boilers, should have a clear water way through the suction valve seats, at each end of the pump, of not less than 40 per cent. of the plunger area; the water way through the delivery

valve seats need not be so large by 10 to 15 per cent., but the common practice is to make both sets of valves alike. The object sought in having large water ways through the valve seats is to afford ample freedom for the water to flow into the pump, the importance of this will be understood when it is known that the flow of water into the pump is due only to atmospheric pressure, and that the flow is interrupted upon each return stroke of the plunger.

The lift of a valve is dependent in a measure upon the valve area, for the same plunger speed the larger the opening through the suction valve seat, the less will be the lift of the valve. Two things are thus secured; a prompt and complete filling of the pump chamber with water from the suction chamber, and a noiseless action of the valves in seating.

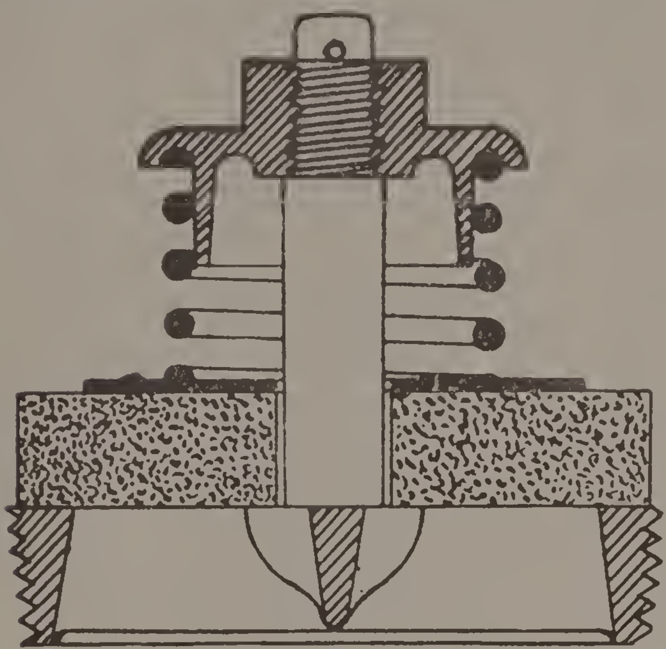


Fig. 55.

Cold water valves, Fig. 55, should be made of pure Para gum sufficiently vulcanized to make them firm without losing elasticity. The best way to get the best valves is to order only such from reputable manufacturers, who can be relied upon to furnish a first-class article. The temptation to adulteration in mixtures of rubber for pump valves cannot always, apparently, be successfully withstood and the result is, a poor valve. The makers of valves are not wholly to blame for this, buyers who insist upon getting a dollar valve for fifty cents can generally be accommodated, in outward resemblance at least; but this is poor economy at best, and may lead to serious consequences at a time when least expected.

A valve plate, which is simply a disc of sheet brass, a little larger in diameter than the openings through the valve seat, should be placed on the back of each soft rubber valve, it adds very much to the stiffness of the valve, it is a means of distributing the pressure of the spring above it over a larger area, and prevents the action of the spring wearing a circular groove in the top of the valve.

Hot water valves made of rubber, to which has been added in addition to the vulcanizing agent, another substance probably graphite, makes a very hard valve, having little or no elasticity, and is not liable to softening when used for pumping hot water. These valves being inelastic require to be ground or scraped to their seats in the same manner as metal valves. Their use is not recommended except for hot water for which they are admirably adapted.

A metal disc valve can be made to take the place of an ordinary rubber valve. It needs only to be of the same diameter and made to fit the spindle upon which it slides, provision being made for receiving the same

spring designed for the rubber valve. The under side of the metal disc should be recessed slightly that it shall have a bearing only at its outer and inner edges, the intervening space spanning the grids of the valve seat without touching. Metal valves and seats must be fitted by scraping or grinding each to the other. The best plan is to scrape either the valve or seat to a face plate and then fit the other to it.

Valve springs should be made of a hard brass spring wire and not of steel. The diameter may approximate one-half that of the valve. The spring should have not less than five coils. Conical springs are not as durable as those cylindrically wound, because in compressing the strain is not equally distributed throughout its length but concentrated usually on the two upper coils.

Air chambers. A single pump should have a large air chamber to relieve the pipes from the shock which occurs at each reversal of the pump; when working under high pressures, and at a moderately fast speed, say 100 feet per minute, the capacity of the air chamber should be, say 3 times the displacement of the plunger at each stroke. The best form of air chamber for a boiler feed pump is that of an inverted cone, Fig. 87, that is to say, a small connection at the pump and a large chamber above it. Such an air chamber is best made of copper. For a duplex pump the size need not be more than half the above, indeed good results are had with duplex boiler feed pumps in which air chambers have been omitted altogether, this is due to the fact that in duplex pumps the motion of one plunger begins immediately upon the stoppage of the other, making an almost continuous delivery.

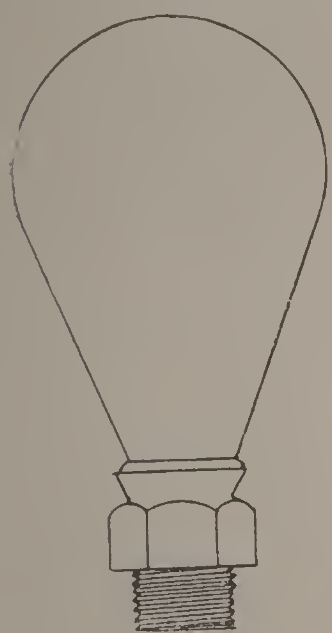


Fig 87.

The steam end of a pump is hedged about by many exacting requirements—and especially is this true of single pumps. A properly designed steam end must be capable of working fast or slow, with light or heavy load, it must make full stroke under all conditions of service, it must be free of everything in the nature of trappy fixtures liable to get out of adjustment. Nearly all single direct-acting steam ends are made with an auxiliary piston, this piston has its own steam valve operated directly from and usually in the same direction as that of the steam piston and water plunger. This auxiliary piston then has a movement directly opposite that of the main piston and by its movement, the main steam valve is carried across the ports of the main cylinder, and thus reverses the movement of the main steam piston. A close examination of the ports, valves, etc., of any make of steam end, having a steam thrown valve, will show that the whole train of mechanism, when under steam pressure, is in unstable equilibrium, and it is this quality which makes it useful in operating a pump.

The movement of steam thrown valves not being positive, they are as a class regarded as having an inferential movement, and in using th

term no disparagement attaches to what may be regarded as an excellent device for the purposes under consideration. By reason of this inferential movement, it is desirable that the pump make as few reversals as possible, and it is largely because of this fact that single pumps are made with long strokes.

A duplex pump consists of two steam pumps of equal dimensions, placed side by side, with the valve motion so designed that the movement of the steam piston of each pump shall have the controlling movement of the slide-valve of its opposite pump, the effect of which is to allow one piston to proceed to the end of the stroke, and gradually come to a state of rest; during the latter part of this movement the opposite piston then moves forward in its stroke, and also gradually comes to a state of rest; but in its forward movement, and before reaching the end of its stroke, the slide-valve controlling the first piston is reversed, and in consequence the first piston returns to its original position, and in nearing the end of its stroke it, in a similar manner, reverses the slide-valve controlling the second piston; these movements are both uniform and continuous so long as steam is supplied to the pistons.

A noticeable feature, and one seldom seen in other than a duplex steam pump cylinder, is that it is constructed with five ports; the two outer ports are for the admission of steam into the cylinder, the two inner ones are for the exhaust from the ends of the cylinder into the exhaust cavity of the slide valve, and the central one is for conveying the exhaust into the atmosphere. The slide valve has neither lap nor lead on either the steam or exhaust sides. There is always a certain amount of lost motion between the valve nut and the jaws on the back of the steam valve, given for the purpose of equalizing the length of stroke of the steam pistons on the two sides of a duplex pump. This lost motion is experimentally determined by the manufacturer and should never be interfered with, the amount of lost motion varies in boiler feed pumps from ⅛ to ½ of an inch, and may not be exactly alike on both steam cylinders.

A common fault of duplex boiler feed pumps is that of shorting up in the length of stroke, for example, a pump having 10 inch stroke may through one cause or another shorten up to 9 inches or less. It is very important, therefore, that, the piston and valve rods be loosely packed, and that all the working parts shall be as free from binding strains as possible.

The steam pistons may be of any approved design, but broad rings should be used in duplex pumps, because the pistons travel over the exhaust ports, narrow rings are liable to work into the exhaust openings in case the ends of the rings should in any case be on the top of the piston.

The compounding of steam cylinders for boiler feed pumps is not often required, in fact compounding is not recommended for the steam end of any pump unless the service is nearly continuous, and not then unless the pressure in the high pressure cylinder is at least 50 pounds. Compounding the steam end of a direct acting pump under favorable conditions may result in a gain of 25 to 35 per cent. Except in the case of very large power stations there will be scarcely anything gained by com-

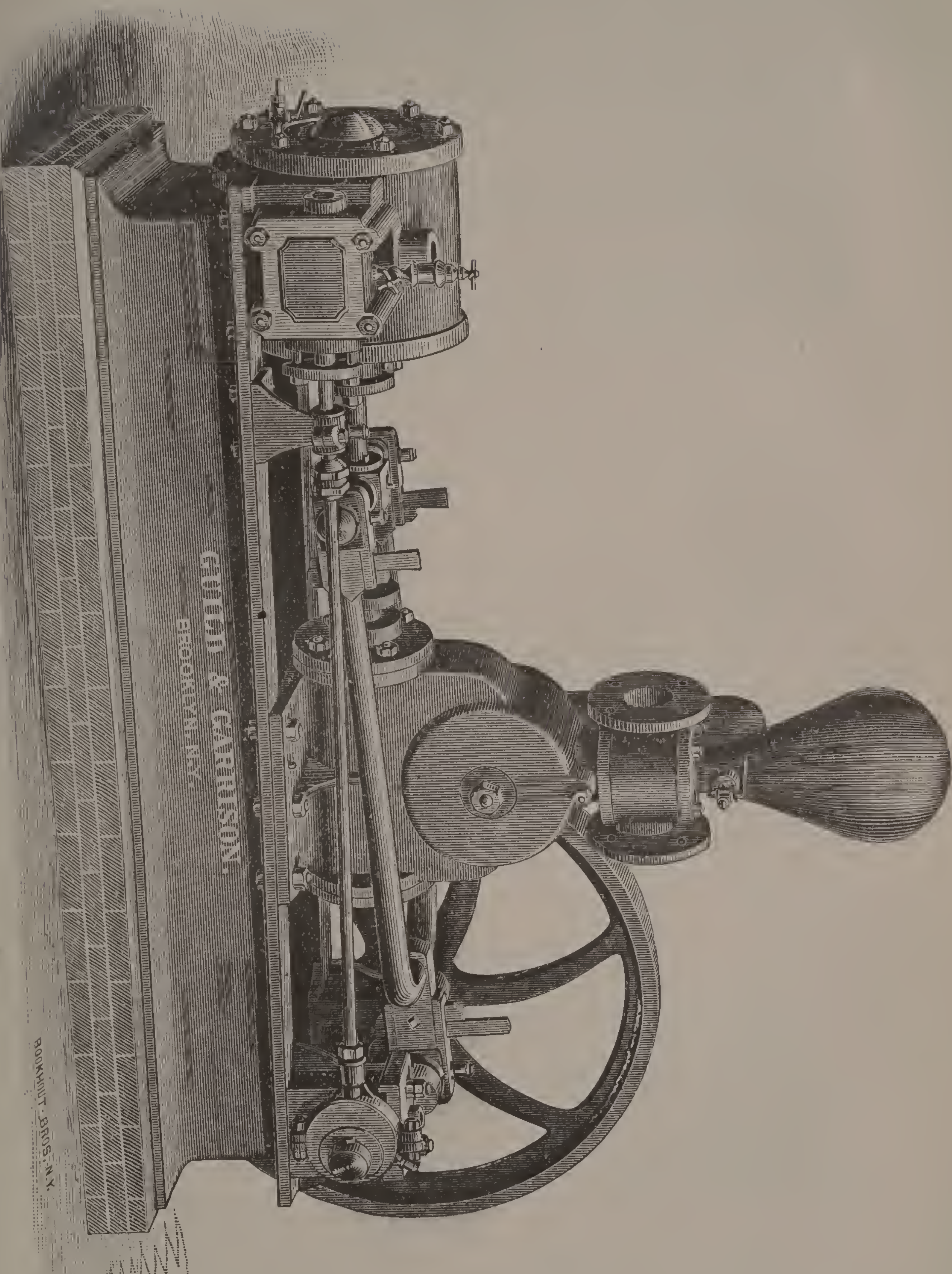


Fig. 148.

pounding and the increased cost over an ordinary pump will be considerable.

Crank and Fly Wheel Pumps, Fig. 148, are more economical in the use of steam than direct acting pumps, for the reason that the steam does not follow full stroke; the maximum point of cut-off in plain slide valve engines is at about ⅝ of the stroke from the beginning. There can be no shortening up of the stroke, as is often the case with direct acting pumps, because the crank movement insures a fixed travel of the piston for each revolution of the shaft, this insures less waste by clearance in the steam cylinders, and a larger displacement in the water end. Pumps of this description are easily had, in the market in both vertical and horizontal patterns. For the same capacity they are higher priced than direct acting pumps, because they weigh more and require more labor in fitting; so that, in the matter of materials and labor alone, they fail of a wider market simply on the question of price.

A power pump is the most economical pump to use so far as expenditure of steam is concerned, because being driven by one of the main engines it shares in whatever economy that engine may possess. In power stations having a line shaft, it is an easy matter to erect a counter shaft for driving a power pump provided there is space enough to get in the proper reducing mechanism. In power stations supplied only with high speed engines and direct connected generators, power pumps cannot be operated so conveniently, and would not, in all probability, be selected. Power pumps are usually of the plunger pattern, from one to three single acting plungers working through outside stuffing boxes; a three plunger pump, with the crank set at an angle of 120° to each other will deliver a stream of water more nearly constant in its flow than any other kind of pump except a rotary.

As power pumps can only be used in connection with other engines in motion, they are not as desirable as self contained pumps, and their use is very much restricted for this reason.

An Artisian well pump, more correctly, perhaps, a deep well pump, consists of a vertical steam cylinder having its piston operated by some form of steam thrown valve gear, the piston rod passing through a stuffing box at the top of the well tubing, and extending down, whatever the depth, to a single acting pump located at or near the bottom of the well. The steam cylinder does not differ essentially from those used on other single pumps, except as to a greater length of stroke. This cylinder is supported on standards high enough to admit of a coupling between the steam and water stuffing boxes, the complete steam end is generally mounted on a base plate fitted to a lower base, are so arranged that the steam cylinder may be moved out of line and thus permit the withdrawal of the pump rod together with its lower bucket and valve. The pump bucket is usually furnished with a ball valve in a cage, a similar valve being located immediately below the stroke of the upper bucket acting as the suction valve to the pump.

The bucket is commonly provided with two or more cup leather packings to insure tightness on the up stroke. A check valve is sometimes

but not always, provided at the surface delivery. If the water is to flow into a cistern in the ground a check valve is not needed, but if the delivery is to be into a tank on top of the building a check valve should be provided at the pump base, the addition of an air chamber above the check valve will greatly lessen the shock in the vertical pipe. The pump rods for deep well pumps should be made of straight grained ash, with wrought iron screw couplings, in preference to sections of wrought iron pipe coupled together as the pipe threads are too fine to withstand that kind of service.

Piping a pump to the sizes indicated by the tapped holes, or flanges furnished by the manufacturer, will yield satisfactory results so far as areas are concerned.

The suction pipe needs especial attention, it should for obvious reasons, be as short and direct as possible. The water flows into the suction chamber of the pump by atmospheric pressure only; Each bend, or change in direction, has a retarding effect, and prevents that readiness of flow so desirable in pumping operations.

An air leak in a suction pipe will soon destroy whatever vacuum is formed within it by the pump plunger, with the one result of failure until this air can be expelled. It is a common practice and a good one, to provide the bottom of the suction pipe with a foot valve, and, where occasion requires a strainer as well.

A side pipe and strainer, is sometimes used instead, in this case the side pipe attaches directly to the suction opening of the pump, the strainer being within this pipe and accessible by simply removing a flanged plate on the top of the side pipe. The strainer is simply a wire cloth cylinder open on the top and closed at the bottom. Twigs, leaves, grass, fish, etc. lodge in this basket like strainer, and are easily removed.

A vacuum chamber is a useful addition to a suction pipe, especially in the case of a high lift, or in case of a long and crooked suction pipe being unavoidable. The vacuum chamber should be as near the pump as possible; it is immaterial whether it connects directly with the suction pipe or not, if more convenient it may be attached directly to the water end itself: Many water ends have two suction openings, in which case the vacuum chamber may be bolted to the opening opposite that of the suction pipe. The size of a vacuum chamber should be about twice that of a single displacement of a water cylinder for a single pump. The effect of a vacuum chamber is to take away from the suction chamber of the pump, the water hammer and other disturbing influences consequent upon a continuous flow into it, and from which the withdrawal of the water is intermittent. The air in the vacuum chamber forms an elastic cushion which will receive the excess of flow without noise, and give it out as silently as it received it. The air is thus partially expanded and compressed at each wave or impulse of the water flowing into the pump chamber.

The limit of suction at the level of the sea is about 32 feet. The practical limitation of suction in ordinary pumping operations is about

25 feet, and at this depth any good pump ought to make satisfactory delivery. The difficulty in high lifts coupled with high plunger speed is that the pump chamber does not fill, and becomes noisy in its operation.

For pumping hot water the delivery ought to be, if possible, into the suction chamber of the pump without lift. This is not always practicable, and for temperatures up to 120° Fahr. a suction lift of 10 to 15 feet may be employed, but beyond this there is too much uncertainty to take the chances unless there is another sonrce of supply to which recourse may be had in case of failure.

The delivery pipes call for no special mention, as they are on the forcing side of the pump. These pipes should follow the dimensions given in the tapped or threaded opening in the force chamber. A gate valve, or a check valve should be included in the piping near the pump for shutting off the water pressure, in case it should be necessary to examine the pump valves.

The steam pipe should be fitted with a union joint below the throttle valve so that the pump could be disconnected, if necessary, while the steam pressure is on.

The exhaust pipe may lead to any convenient place for utilization in heating the building, into a feed water heater, or directly into the atmosphere.

Drainage pipes should be provided for carrying off any water of condensation which might collect in the steam cylinders.

A charging pipe leading from an overhead tank into the suction chamber of the pump, or into the suction pipe, is a useful device for filling the pump and pipes with water, discharging any contained air at the same time.

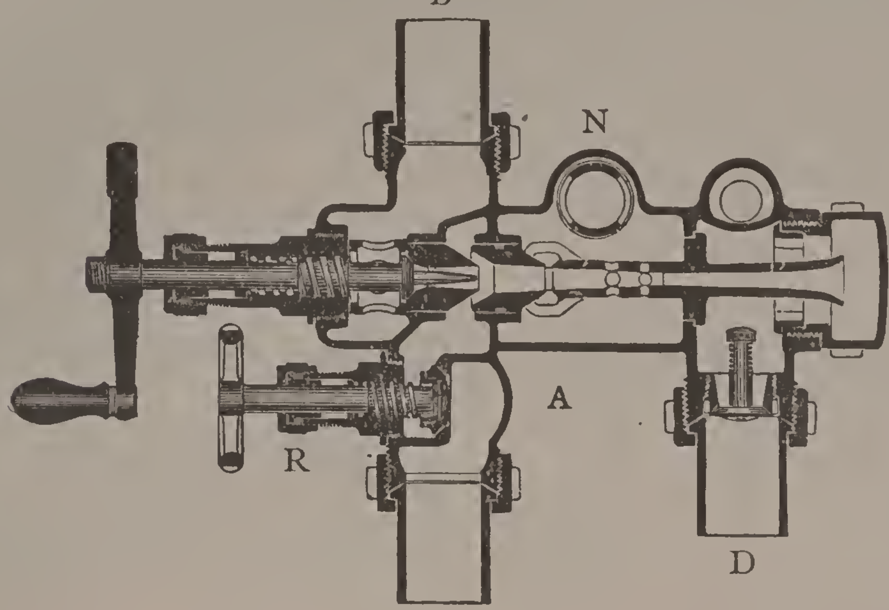
The injector has been for many years an active competitor of the direct acting steam pump. This ingenious piece of mechanism is, without doubt, the simplest apparatus yet devised for feeding steam boilers. The injector, like all new devices, the principles of which are not generally understood, was a long time getting that full recognition which its merits warranted.

The commercial arguments in favor of the injector are the small space occupied, good wearing qualities, the returning of the heat in the steam back to the boiler by the rise in temperature of the feed water, that they are comparatively noiseless in operation, their first cost is very low, and are not liable to serious derangement and, therefore, economical in the cost of maintainence.

The accompanying illustration represents in sectional elevation a Seller's fixed nozzle injector which may be taken as illustrating the salient features of injectors generally.

It will be seen that the instrument is quite simple in its construction, notwithstanding its applicability to varied conditions of service : A is the body or case of the injector ; B is the *steam* connection leading from the steam-space in the boiler ; C is the *water-supply* connection, in which is situated the water-regulating valve R ; D is the *water-delivery* connection, containing a check-valve, and leading to the boiler. The overflow-

valve N may be shifted to either side of the injector body, and turned radially, so that the injector may be placed in any position that will permit it to discharge the overflow vertically downward.



The action of the injector depends upon the momentum of a jet of dry steam moving at a high velocity, transferred to a body of water cold enough to condense this steam and moving at a lower velocity, the momentum thus acquired by the water being sufficient to overcome the friction of the feed pipes and valves, and enter the boiler at the same steam pressure as that of the incoming jet.

The suction lift of an injector should not exceed 15 feet to get the best average working results, though 18 to 20 feet is permissable at the cost of lower efficiency.

The water supply should be at a continuous temperature, the lower the temperature the easier it is to create and maintain a vacuum within the instrument, if the water supply be at a temperature of say 120°, more water will be required to condense the incoming jet of steam than if the temperature were 60°, retarding the velocity of the steam jet, and at the same time reducing the power of forcing the water forward. The water supply for high pressures should not exceed 100°; for low pressures, the temperature should not be higher than 130 to 140° and then only on very low lifts.

On account of the small openings through the nozzles of an injector, it is important that the water supply be very clean, because small particles of floating matter, sand, grit, etc., which would pass through a pump unnoticed, will in all probability stop its action, and will require to be taken apart to remove whatever may have lodged therein.

The quantity of water carried per pound of steam varies somewhat with the make of injector, but on an average one pound of dry steam will deliver into the boiler about 16 pounds of water against a gauge pressure of 100 pounds.

The rise in temperature of the feed water is due to the condensation of the jet of steam within it, which gives it motion. Hutton explains this action in supposing 1 pound of steam in motion to be mixed with 2

pounds of water at rest, the result produced would be 3 pounds put in motion at one-third the original velocity of steam. The velocity of water or steam issuing into the atmosphere from the same boiler, is equal to that acquired by a falling body in falling through the height of a column of the same water or steam giving the same effective pressure. And since the velocity acquired by a falling body is proportional to the square root of the height through which it fell, it follows that the velocity of the water and the steam would be proportional to the square roots of their relative volumes.

The volume of steam with one atmosphere effective pressure, or 30 pounds absolute pressure, is 827 times that of water, it would issue with the square root of 827=28.76, or say 29 times the velocity of the water from the same boiler. Hence the steam issuing would just balance 29 times its own weight of water trying to issue from the boiler. The number of units of heat in 1 pound of steam at 30 pounds absolute is 1159 Fah., and assuming the original temperature of the feed water at 100°, the rise in temperature of the feed water would be :

$$\frac{1159 \text{ units of steam}-100^\circ \text{ water}}{29+1}=35.3^\circ \text{ Fah.}$$

with steam at 1 atmosphere effective pressure, or 30 pounds per square inch absolute pressure.

Injectors are classed * as single jet injectors—double jet—automatic or restarting—self-adjusting, open overflow—closed overflow.

The automatic exhaust steam injector is a simple and efficient boiler feeder worked by the exhaust steam from a non-condensing engine, instead of live steam from the boiler. Such an injector works at but little pressure above that of the atmosphere, and, while not in as general use as the live steam injectors has proven a very satisfactory device where the conditions are favorable to its use.

The Inspirator differs from an injector in being a double instrument one-half of which is a lifting and the other half a forcing apparatus ; the lifter drawing the water from a well or tank and delivering it to the forcer, which then delivers it to the boiler, and at any steam pressure without adjustment.

To enter fully into the history, theory, developement and description of the varieties of injectors and ejectors now in the market, would require more time than is at our disposal this evening.

I thank you for your attention at what may seem to have been a rambling talk about pumps, but if you shall have caught an idea either as to the construction, care and management of boiler feed apparatus, I shall feel that my efforts have not been wholly lost.

* Kneass.

UNDERGROUND CONDUITS AND CONDUCTORS

BY

JOSEPH D. ISRAEL,

SUPT. OF STREET WORK.

After having obtained the consent of the City Fathers to lay and maintain underground conduits and conductors, the question that confronts the engineer is—what is the most feasible system for this construction? The points to be considered are capability of inspection in every part, ease of removal or replacement with the greatest possible rapidity, and furthermore, the least possible obstruction to the public highways—the latter being a more important consideration than many would at first believe.

In a large city in which the municipality, as well as numerous private corporations are continually constructing sub-structures, the consideration of economy of space is an imperative duty of the engineer, particularly in a city like Philadelphia, where the narrow limits of the streets necessarily drive us all into cramped quarters. The question of durability, which naturally includes repairs, is of paramount importance, as one of the thorns on our rose bush of prosperity is the expense of street repairs and maintenance.

No doubt, many of you are at a loss to understand why the cost of construction has not been mentioned; and in explanation of this I will say that since the days of Adam, the first consideration in every undertaking has been, "how much will it cost?" The presumption is that the item of expense always enters into every operation, and that it is the duty of the engineer to exert his efforts to obtain the best and most practical material, while it is the duty of the financier to hold in check any contemplated extravagant expenditures. The consultations between the two will lead to the proper solution, that is, obtaining the best material at the least possible cost, within such a limit that the returns of operation will not give the directors and stockholders of the operation any cause for complaint.

Our foster father, Edison, has said—"Practical experience is better than theory every time"; and I will therefore attempt to describe to you the result of my experience in this work, especially dwelling upon the Edison system, which concerns us all most directly.

After a moment's reflection, it is manifest to all of you that the advantages of an underground system are so numerous, when held in comparison with the overhead, or aerial, lines of distribution that any comment, almost, seems superfluous.

In the matter of first cost, the advantage is decidedly in favor of the overhead lines, except as in the Edison system of distribution, where the conductors used for mains and feeders are necessarily larger than the ordinary aerial telegraph or telephone wires. In such cases the cost of suspending the wires on suitable supports is almost as much as for the introduction of an underground system.

The cost of introduction of an overhead line would be considerable less than the undergroud line, were it not for the fact that all overhead lines are subjected to the changes of temperature, lightning strokes, as well as accidental injury from wind, snow and sleet. To such an extent do these conditions operate against the system, that it is a fact in certain localities, wholesale renewal of wires is necessary every few years, owing to the destruction of the lines due to violent storms. Futhermore, the multiplicity of wires is such, that the overhead lines are undoubtedly a disfigurement to our highways, as well as a menace to life and limb, through the possibility of their crossing with other electrical wires of high tension, and by falling from their supports. An interruption in the service is a serious loss to the Company operating the wires.

All the large cities attempting to keep in the front line of progress are now compelling by law, electrical corporations to remove their overhead lines, and to place the same underground. At first there was considerable objection raised by the corporations on acconut of the additional expense to which they would be put, as well as the claim set up by them that the underground system could not be successfully operated. In places where the underground system has already been established, the returns are giving a profit on the investment; and the practibility of the system has been demonstrated so successfully, that in spite of the opinion of able men who spoke against the system, every electrician will to-day state that if properly constructed, the underground system will give entire satisfaction for electrical work.

We are then well satisfied that the experimental stage of underground conduit construction has been passed, and we are ready to accept the fact, that in large cities where the work to be done is confined within a small territory, the underground system can be constructed and operated as economically as the overhead lines, in view of the conditions which have to be met.

There are essentially two systems of conduit for underground use.

The one in which the cable is drawn into the pipe or opening, from which it can readily be withdrawn if necessary, this we call the "open" or "drawing-in" system; the other in which the conductor is solidly built in an insulated pipe—that we call the "built in" system.

In the "drawing in" system, we have pipes or tubes lying side by side and upon each other, connected in such a manner that we have a number of openings, continuous from man-hole to man-hole, these manholes being located usually at the intersection of streets.

In the "built in" system, the copper conductors are encased in an iron pipe, cut in convenient lengths and connected while being laid, giving us one continuous line between terminal points.

The advantage of the "drawing in" system is the capability of making tests and repairs in any manhole, thus subdividing the conductors into short lengths, and locating faults which may arise without making any openings in the street paving. This is a decided advantage in convenience, time and cost, and does not interfere with the traffic of the streets. We cannot make repairs to the conductors in the "built in" system except by opening the streets at each particular place, required by the work to be done.

Considering the material most commonly used in the construction of the conduits, for practical purposes we have wood, iron and terra-cotta, or as is sometimes termed, vitrified clay. Up to the present time, the most extensive use has been made of wood.

It is popularly supposed that wood will rot and decay within a short time when buried under ground. In the course of our work we have often uncovered sections of wooden water pipe, which were in use over forty-years. These pipes consisted of a hole bored in the centre of a circular log. Had it been necessary, they would still have answered their original purpose, for although the outer surface had, in some instances started to decay, the bore of the log and the fibres in close proximity were still in almost perfect condition.

In our electrical wooden conduits, we are further advanced in the point that instead of untreated wood, we use creosoted timber. This creosoting gives a lasting quality to the timber that materially helps it to withstand the ravages of age and consequently prolongs its life and usefulness.

Creosoted timber is obtained by treating the lumber (preferable yellow pine) with dead oil of coal tar, which is the pitch obtained from bituminous coal which contains an oily acid and tarry matter.

The creosote in itself has a detrimental effect on the lead coverings of the cable, which are drawn into the conduit. At times we have been compelled to remove sections of our cable on account of the lead having been destroyed through the formation of carbonate of lead; giving the cable the appearance of having been partially eaten away, thus forming a white crust on the outer surface of the lead.

It is claimed that the destructive effects of freshly applied creosote disappear after a few years; but this claim is open to serious doubt, and a conscientious man could not afford to experiment with creosote in a business operation, and it is his duty to guard against it.

To overcome the chemical action, cables have been covered with a cotton or hemp braiding over the lead, and latterly we have used a composition of asphalt and jute which is, apparently, preventing the decom-

position of the lead and will no doubt withstand such action for many years.

In European countries creosoted timber has been in successful operation for over fifty years, and in this country it has proven its indestructibility when buried in the earth for over twenty-five years. An important fact to be closely considered is the manner in which the timber has been treated with the coal tar, for to thoroughly preserve the timber all germs of decay must be removed and the timber thoroughly saturated with the tar. A mere outside application would give us an apparently good conduit with a diseased internal organism, which would shortly manifest itself in the utter deterioration of the conduit.

Unfortunately the Edison Electric Light Company of Philadelphia was forced by political legislation to make use of a wooden conduit which is only an apology for an underground construction. This was simply plain boards roughly nailed together, the boards having first been painted (you cannot say treated) with a tar composition. Naturally the thing very rapidly turned into dry rot, and in the few cases where the company was positively compelled to make use of some of the ducts or openings, they have already been required to remove the entire structure and replace it with more modern improvements.

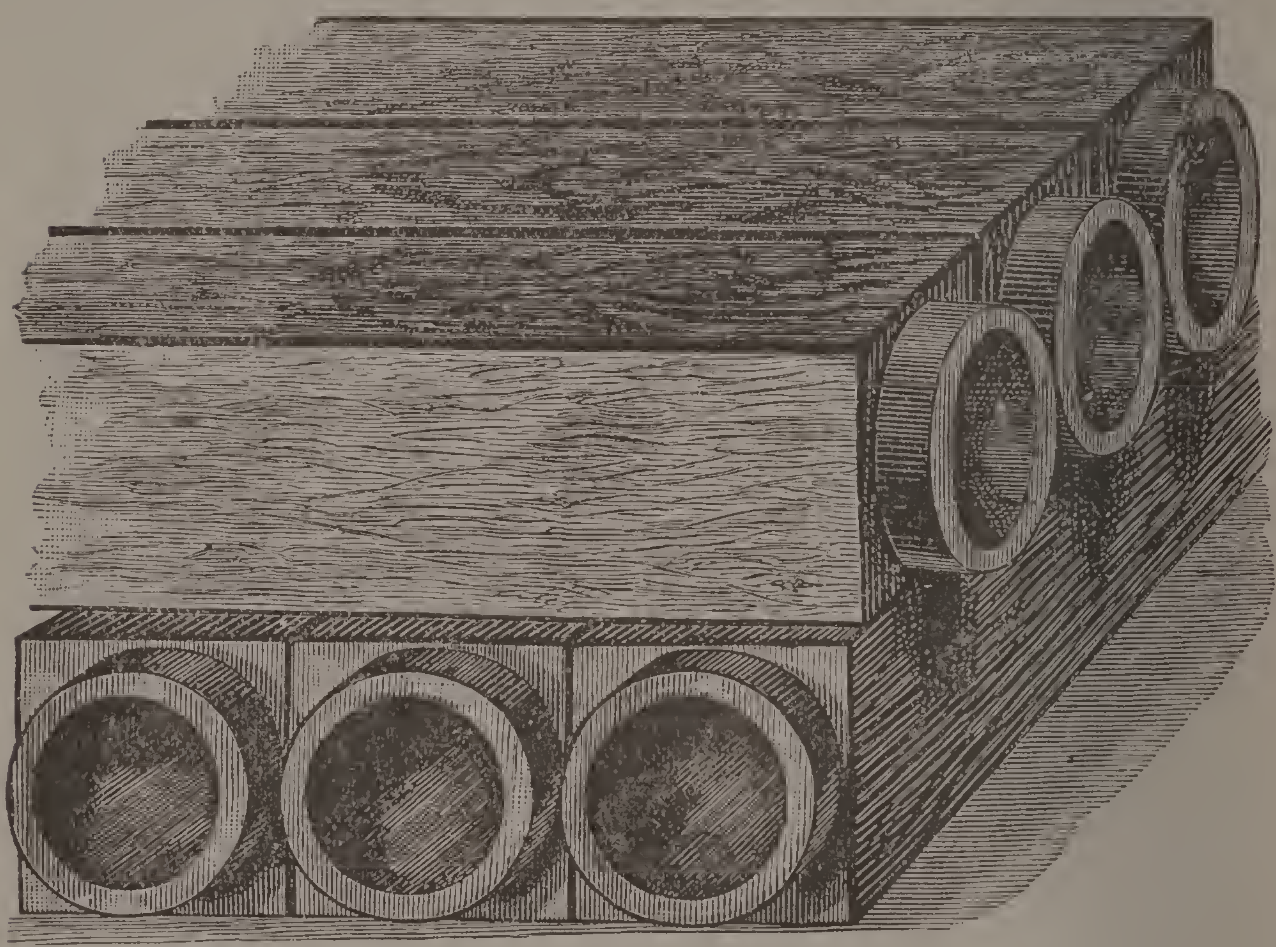


Fig. 1.

Among the wooden conduits used extensively, and whose usefulness have been proved, is the tubing, Fig. 1, which you see is the old fashioned pump log, made with a groove at one end, and a tongue at the other. These are easily fitted into each other. A dash of tar paint is used on the tongue before slipping it into the groove, thus giving a better pro-

tected joint. These tubes are laid above each other in tiers and no nails are required in the construction. The absence of nails removes a factor of danger from mechanical injury in drawing in conductors. "Look out for nails,'' would be a good watch-word to establish when engaged in conduit work.

Somewhat similar in principle, but different in design, is the wooden conduit, Fig. 2. This is made in sections of any desired number of ducts.

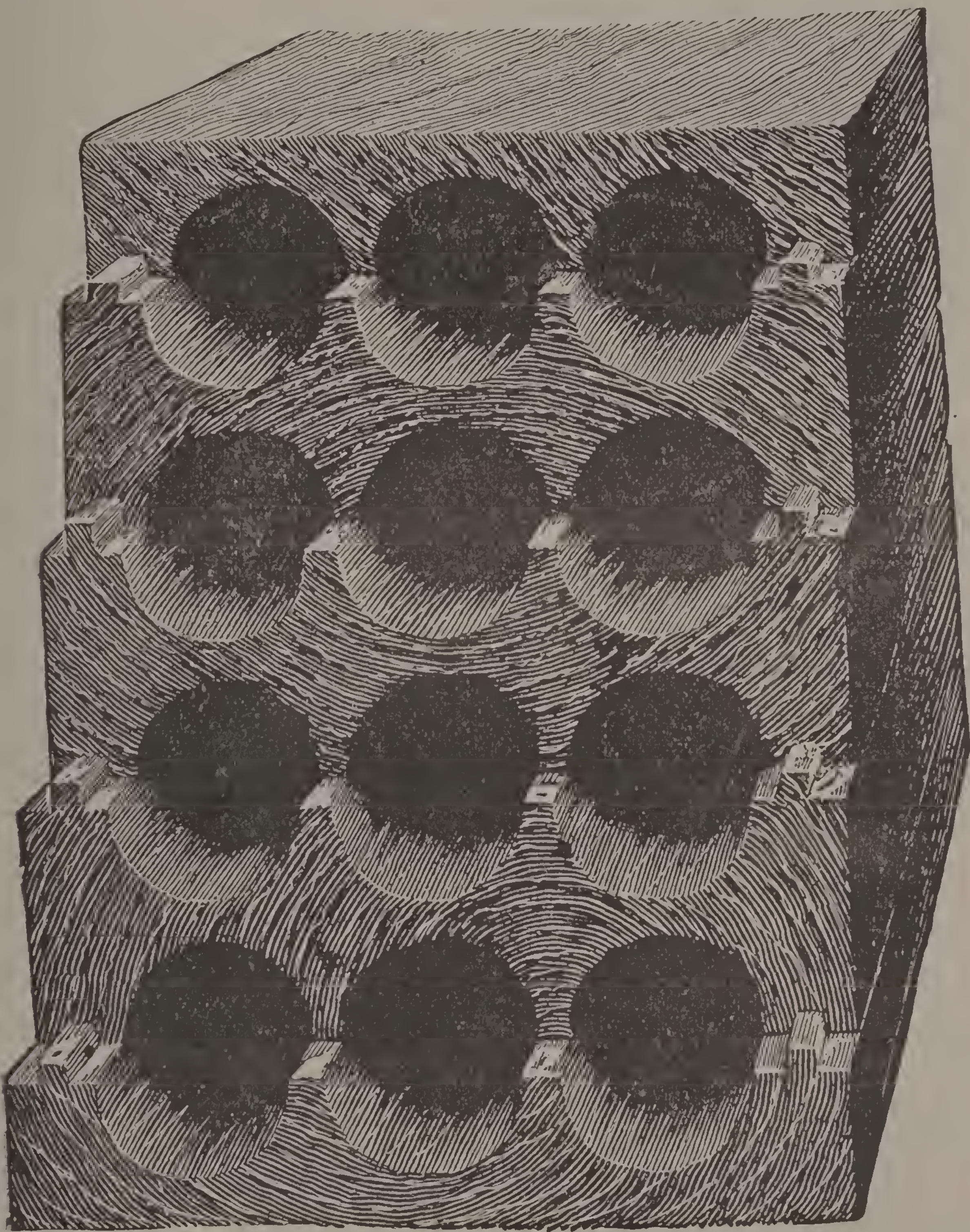


Fig. 2.

The top and bottom pieces contain the upper and lower halves of the openings. Center pieces are then added, as you can readily see, to increase the conduit to any desired size. There is a groove on the outer edge of each section, and a tongue is used in joining the sections together. A later idea is to use a strip of felt on the outer edge in place of the tongue and groove. Of course, nails are used in joining these sections,

and care must be exercised in fitting the ends of the lengths. By mitering the ends, we can deviate from a straight course, an operation which must be frequently performed in practical work. It is customary to lay a plank on top of all these conduits to prevent any damage being done by parties engaged in other work in the streets. In order to attempt to make a water tight joint, pieces of felt are tacked around the outside seams and then painted with pitch.

Among iron conduits, we have the cast iron pipes, which are fitted into the adjoining pipes by means of a screw thread cut at the ends. Iron is not an insulator to any extent at all, and is therefore not well adapted for electrical work where the conductor comes in direct contact with the iron. There is a certain amount of self induction set up, and consequently a loss of electrical energy. The joints between the sections of the pipes present sharp edges which are liable to cut the cable as it is drawn in, and the iron corrodes and forms scales on the inside of the pipe, which is detrimental to the insulation of the conductor. The sharp edge of the pipe terminating in the manhole is also liable to cut the cable.

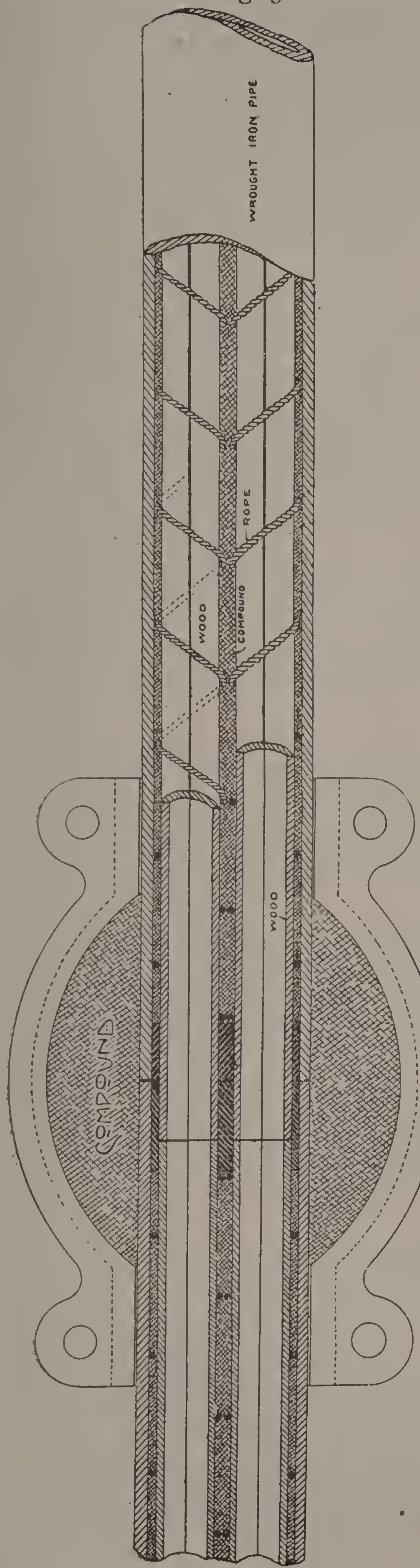
Other forms of iron conduit are those in which we have what might be called lined tubes. One system consists of a light cast iron rack holding a series of tubes. The space between the tubes is filled in with an insulating compound composed chiefly of pitch. These tubes are similar to the interior conduit used for inside work.

They are a specially treated preparation of a paper conduit covered with a light cast iron armor. These pipes take the shape of a telescope, one fitting into the other and a sleeve is run over the joints. The interior of the conduit being composed of insulating material throughout its entire length. It is claimed to be air tight and moisture proof, and therefore admits of the use of bare copper conductors, thus saving the cost of cable insulation.

The use of bare conductors requires an extra precaution to be taken in the manholes, in order to carry the conductors across the space where they will be subjected to the conditions of the weather, as well as the danger of coming in contact with parallel and intersecting wires. To overcome this, the section of the conduit entering the manhole is expanded in a forked form and also in a vertical line to allow more space for the conductors, and then a short pipe projection is provided to be carried across the manhole to the opposite section of pipe, thus making the insulated tube complete.

Another form of iron conduit is a wrought iron, cement lined pipe. This conduit consists of a wrought iron shell, $\frac{1}{16}$ of an inch thick, rivited, and lined with $\frac{5}{8}$ of an inch of cement concrete. The ends are ball and socket, so as to give an assurance of good joints and alignment. The desired number of these pipes are laid in a matrix of cement. A mandril is drawn through these tubes to smooth the inner surface. There is a danger which suggests itself in cement lined tubes in the formation of scaly teeth from the cement, on account of the mandril not catching and thoroughly scraping all the loose material. These teeth make it difficult in some cases in drawing in the cables as they take hold of the outside in-

Fig. 3.



sulation, cutting and preventing the cable from being drawn through. This occurred at a point in Philadelphia with a feeder cable of one of the electric railway lines, and necessitated an opening of the street to make repairs.

Another form of the drawing in system is the conduit as shown in Fig. 3. This system might be classified as a combination of the iron and wood conduits. The conduit consists of split wooden ducts, which are separated from each other by spiral windings of rope. The wood and rope are specially prepared by being boiled in oil. A number of these ducts are held collectively together by an outside spiral binding and placed in an iron pipe.

The space between the wooden ducts and iron pipe is filled in with an insulating compound. A plug is driven in at the ends. At one end the ducts project 1½ inches beyond the end of the pipe, and at the other end recede for the same distance. The pipes are made in twenty foot lengths, and the sections are joined by the projecting ends of the ducts slipping into the plug which holds the receding ends of the ducts in the next pipe.

The joints are protected by a cast iron box covering, which is also filled with an insulating compound. In the manner of details as to distribution, service connection, &c., the system is somewhat similar to the Edison system which will be described farther on.

It is intended that this conduit should be used for bare conductors. The smoothness of the inner surface of the ducts permits of ease in drawing in the conductors. The protection afforded the joints by the iron coupling box prevents water or moisture from reaching the conductors.

This is a comparatively recent invention and up to the present time little opportunity has been given us to test its practicability. From descriptions furnished it appears to be a meritorious system.

In the class of earthen-ware conduits we have the glazed terra cotta or vitrified clay conduit. It is cheaper than iron but not as cheap as wood for underground construction. A bed or incasing of concrete about 6 inches thick is laid around each tier, and then the whole body of the conduit is incased in a similar concrete bed.

This system is used in Washington City by the U. S. Government. The stoneware offers a very hard and smooth surface, but at the same time it also offers objections on account of its liability to fracture and the difficulty of making good joints. The ends of the sections butt up against each other, a slight offset being made at each length. A cover is then provided to overlap the joints, a mandril or scraper being drawn through to clear the ducts, and the conduit is then covered with concrete.

This conduit will not adapt itself to the depressions or inclines occasioned by intersecting lines, and in such cases it is usually necessary to build extra manholes and cross the obstructions with iron pipes.

There is no chemical action on the lead conductors, but condensation is set up due to the changes of temperature which keeps the inside of the conduit moist to a certain degree, a very undesirable condition for electrical purposes.

After investigating the various makes of conduits and examining them in actual working condition, the conclusion must be reached that in spite of claims set forth by manufacturers, it is a physical impossibility to produce an absolutely water-tight conduit. The mechanical protection offered to the cable is the point to be considered in conjunction with the other points as previously mentioned.

After careful investigation it appears that wood answers the purpose as well, if not better than any other material, on account of cheapness, flexibility of alignment and compactness. The pump log style is easily laid, requiring neither experience or adept workmanship nor accessories of any kind in its construction. No nails or troublesome joints. The same material answers for any number of ducts, placing in the ground the required amount as the work progresses. If the space beside the pipe is filled in with asphalt we have a very substantial structure. The creosote is the only objectionable feature, and it is overcome by chemical proof insulation.

The manholes are best built of brick with an iron frame top. A recent invention gives us a top cover in the shape of a bowl filled with the same material as the street paving. This is very desirable when filled with asphalt on newly paved streets. It renders visible only the outer iron band of the cover, thus removing any unsightly iron from the street surface, and at the same time is practically noiseless.

The rodding or piloting of these ducts, although a very simple matter, calls forth many ludicrous questions from curious people on the streets. The workmen have a set phrase in answer to the inquiry "How did you get the rope through?" It is "We had a piece of cheese at the other end

and we sent a rat through with a string tied to his tail." Now for a fact ferrets have been used in London, but at present that is not the usual custom of procedure. We have a number of small lengths of rods with a screw and socket at the end. In one manhole we screw these together and push them through the duct until the first rod reaches the far manhole. The rods are then disconnected and pulled through until we reach the last rod which has the rope attached to it.

A useful invention for laying the pilot wire through conduits, is the Cope pilot.

This machine can be operated by a man standing above ground and thus avoids the necessity of working in the manhole.

The operating lines act directly on the head of the machine and its gripping parts, so that all the power applied to the operating lines is exerted equally in moving the machine forward about 5 feet with each movement. This movement is effected by means of a pulley gearing and grip, and in case of meeting an obstruction, can be thrown out of gear and withdrawn.

In the matter of cable conductors, it has been found, as previously stated, that for the protection of lead a jute, asphalt or braid covering is required in such places where the cable is liable to be subjected to chemical action. The insulation for the copper conductor is in most cases either a form of rubber or gutta-percha or some fibrous insulation such as jute.

The rubber is susceptible to the changes of temperature and although much in use, it has given considerable trouble in the past, particularly when it has been placed near underground steam pipes. The vulcanizing effects of rubber have proven to be detrimental to the copper itself, chemically decomposing it on account of the sulphur which rubber contains.

The jute insulation containing a quantity of resin has stood the test of time, and has proven itself satisfactory. It is pliable and is impervious to water. The question of insulation is not so much one of quality as it is one of quantity. In other words, to solve the question of insulation, "give the copper more rope."

In the "built-in" system of underground construction, the conduit and conductor are necessarily combined. In this class we have the system as used by the Edisod companies, popularly known as the Edison tube.

In the three wire form of distribution, this tube is composed of three copper rods. Each copper rod is spun over separately with a prepared rope and then placed in a triangular position and wound with a fourth rope. The coppers thus separated are placed in position in the center of a lap-welded steam pipe, from which the air has been exhausted by means of a vacuum pump. The pipe is then filled with an insulating compound composed chiefly of asphalt, Trinidad tar and linseed oil. This compound fills up all the open space in the pipe, and rubber plugs are used to close the ends. The pipe is then painted to preserve the iron from rust, the finished product gives us the Edison tube, consisting of

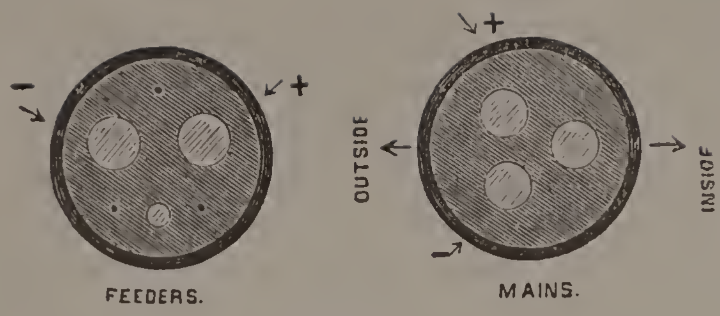


Fig. 4.

three copper conductors insulated from and protected by an iron armor. This tube is therefore both conduit and conductor ready to be laid in the ground.

In the Edison system of distribution, the tubes are divided into the two classes of Feeders and Mains.

Feeders run from the station to various centers of distribution. Their function is to keep up the supply of electricity, and their terminal point may be considered as a current pool from which the attached lines draw their supplies. The advantages of the three wire system for a saving in copper, are familiar to all electricians, and it is in the feeder tube that this is at once made self-evident. In the feeder tube, one conductor is smaller than the other two. That conductor is called the neutral wire. The larger conductors being the positive and negative wires.

By referring to Fig. 5, you will see that the middle or neutral wire can

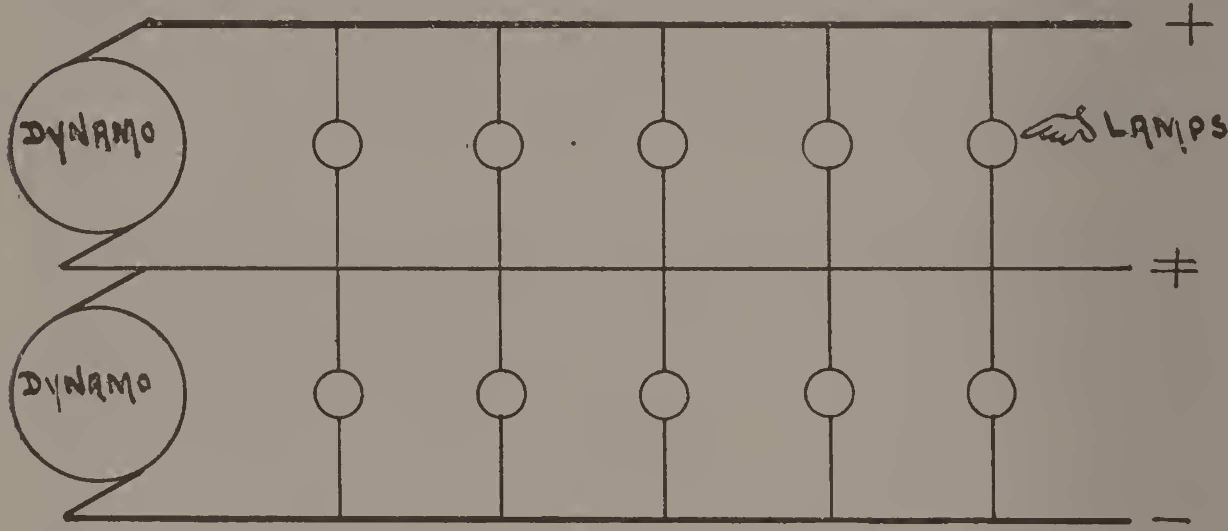


Fig. 5.

be made of a smaller size than the two outside, or positive and negative wires, because the current flows from the upper dynamo along the positive wire through the upper lamps and back along the middle wire to the negative terminal of that dynamo. The current from the lower dynamo flows along the middle wire through the lower lamps and back along the negative wire to the negative terminal of that dynamo. If the current required for the two groups of lamps are equal, no current will flow along the middle wire; but it will flow from the positive terminal of one machine through the two sets of lamps and back to the negative terminal of the other machine; and then the middle or neutral wire will carry no current. If the current on each division is not equal, then an amount of current will flow along the middle wire, which will represent the differences in amounts between the two divisions or sides of the system.

In Central Station practice, it has been found that this difference will never be more than one-third of the maximum current consumed. Therefore it is safe to have the area of the neutral conductor one-third of the size of the outside conductors.

In addition to the three conductors, you will see three small wires in the feeder tube, which are called the pressure wires, These wires form an independent circuit from the center of distribution to the Station ; and enable us to read, by means of suitable apparatus, the electrical pressure, potential or voltage at the end of the feeders. We have one wire for each polarity, and through the means of regulating apparatus, we can control the pressure until the desired effect is reached.

In the main tubes there is no necessity for pressure wires, as the mains radiate from the centers of distribution and loop the ends of the feeders together. All services to supply consumers with electricity are tapped from the mains. As we can neither control nor dictate to the consumer, no matter how carefully we balance the system, a number of customers on one square may turn on all the lamps on one side of the system only. In order to guard against such an event, we do not reduce the size of the neutral wire in the main, but keep all three conductors of the same size.

The feeder has, as a rule, four radial mains ; and there is in it less probabitity of such an unbalancing as the load on these four mains will tend to counterbalance each other,

These tubes, Fig. 6, are cut in standard lengths of 20 feet 4 inches,

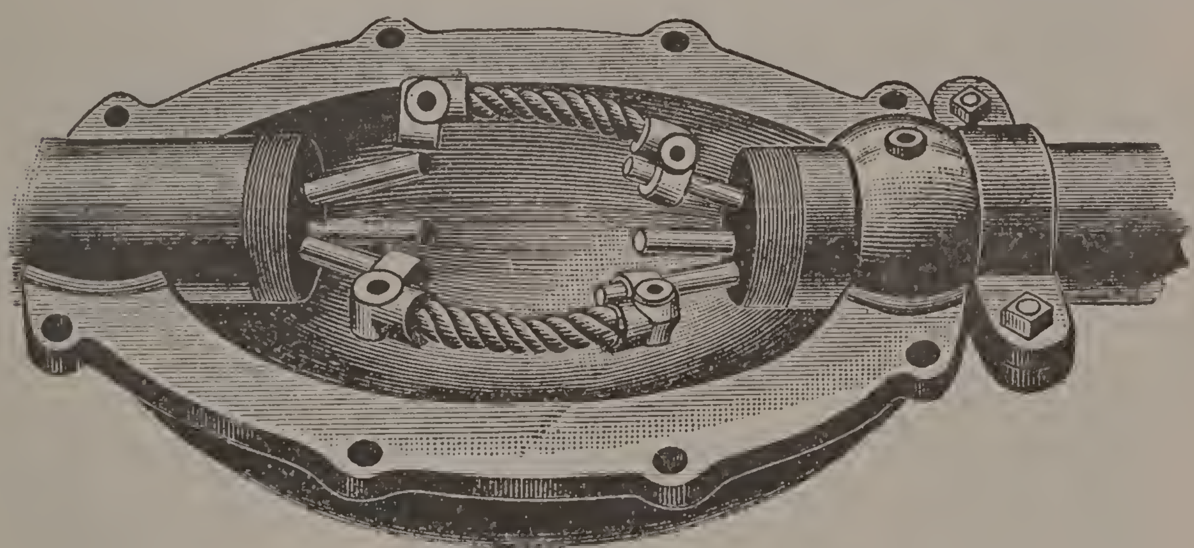


Fig. 6.

with two inches of copper conductors projecting at each end. These coppers are connected by means of coupling jointts consisting of flexible cables with sockets cast at each end. The main joints have holes bored through the sockets to allow for service connections. These joints are carefully soldered. A ball and socket clamp which allows some flexibility is attached to the tubes, and the joints are protected by an iron coupling box, made in two halves to be bolted together. This box is filled with insulating compound, and if the work has been carefully and properly done we have an excellent connection of and protection to our conductors.

For elbows, bends aud such like deviations from a straight course, the joints are made shorter or longer as required, and the boxes are made at the various angles of 20 degrees, 55 degrees and 90 degrees, thus allowing us to lay the tubes at right angles or any intermediate point from the straight line.

These tubes when used for feeders are not as satisfactory as cables drawn through conduits. The trouble with the tubes lies in the number of joints and the difficulty of getting at them. To overcome this difficulty, man-holes are built at the intersection and bisection of all streets, so as to include all coupling boxes on the feeder lines. Furthermore faults are more likely to develop in tubes, and are more difficult to locate. Cable faults are easily located and quickly repaired.

For mains these tubes excel the use of cables. In order to connect services it is necessary to cut the main for each connection. A cable once cut is liable to deteriorate, and a fault will probably develop. With the Edison tube, we simply go to one of the joints, remove the straight coupling box, solder the coppers of a three wire lead covered service cable into the holes of the main coupling joint. We replace the box with a similarly constructed Tee box, and refill it with an insulating compound, and we then have as good a joint, as well protected, as was originally on the main.

For service conductors we use a lead covered cable with jute insulation. This cable being flexible allows us to cross obstructions in the street and readily conforms to all necessary bends, inclines or depressions.

In order to connect the feeder and mains at the center of distribution, we have a safety fuse box called the Junction box.

A safety fuse is a strip of lead of appropriate length and thickness, connected at the ends with copper contact pieces, provided with a slot allowing it to slide under the binding posts. The length and thickness of a strip are so constructed as to carry only a certain desired amount of current; and as soon as it is overheated by a greater amount of current passing through it, it will fuse and melt, thus preventing the conductor of which it is a part, from overheating and burning out. It is therefore all that its name implies, a safety fuse. It not only protects its own line from probable burn-outs, but it also prevents faults from spreading to other lines. It is the known weak point of the conductor, and arrangements are therefore made to have ready and convenient access to it. It is consequently placed in the junction box.

The junction box serves then, first as a center of distribution; second, as a center of equalization of electrical pressure between the different parts of the system. These boxes afford a convenient means of inspecting the fuses and admit of a subdivision of the mains into short sections, and thus aid in localizing faults. A Junction box is placed at all the intersections of the streets.

These boxes, Fig. 7, are made of cast iron with double covers. The inner cover is made water-tight by the use of a rubber gasket. The cover is screwed down with heavy nuts, and the seam around the edge is filled with wax and tallow. It is seldom that any water finds its way into these boxes after they have been properly sealed.

The stubs at the bottom of the box contain short pieces of tubes for use in connecting with the feeders and mains leading into the box. In the inside of the box, cables lead from the stubs to terminal pieces placed on insulated blocks at the top. These cable terminals are opposite rings to which are attached all conductors of like polarity.

The centre of the box consists of three rings of different polarity, insulated from each other by rubber plugs. This arrangement enables us to tell the polarity of each conductor by the position it occupies in the box. In addition to the rings, there is a small rubber plate holding binding posts for connecting the pressure wires of the feeder tubes.

Experience and care in the laying and connecting of these materials aids much in lessening the probability of future trouble and it is therefore well to exercise especial care in the installation of the system, as it will undoubtedly lead to a saving in the cost of maintenance.

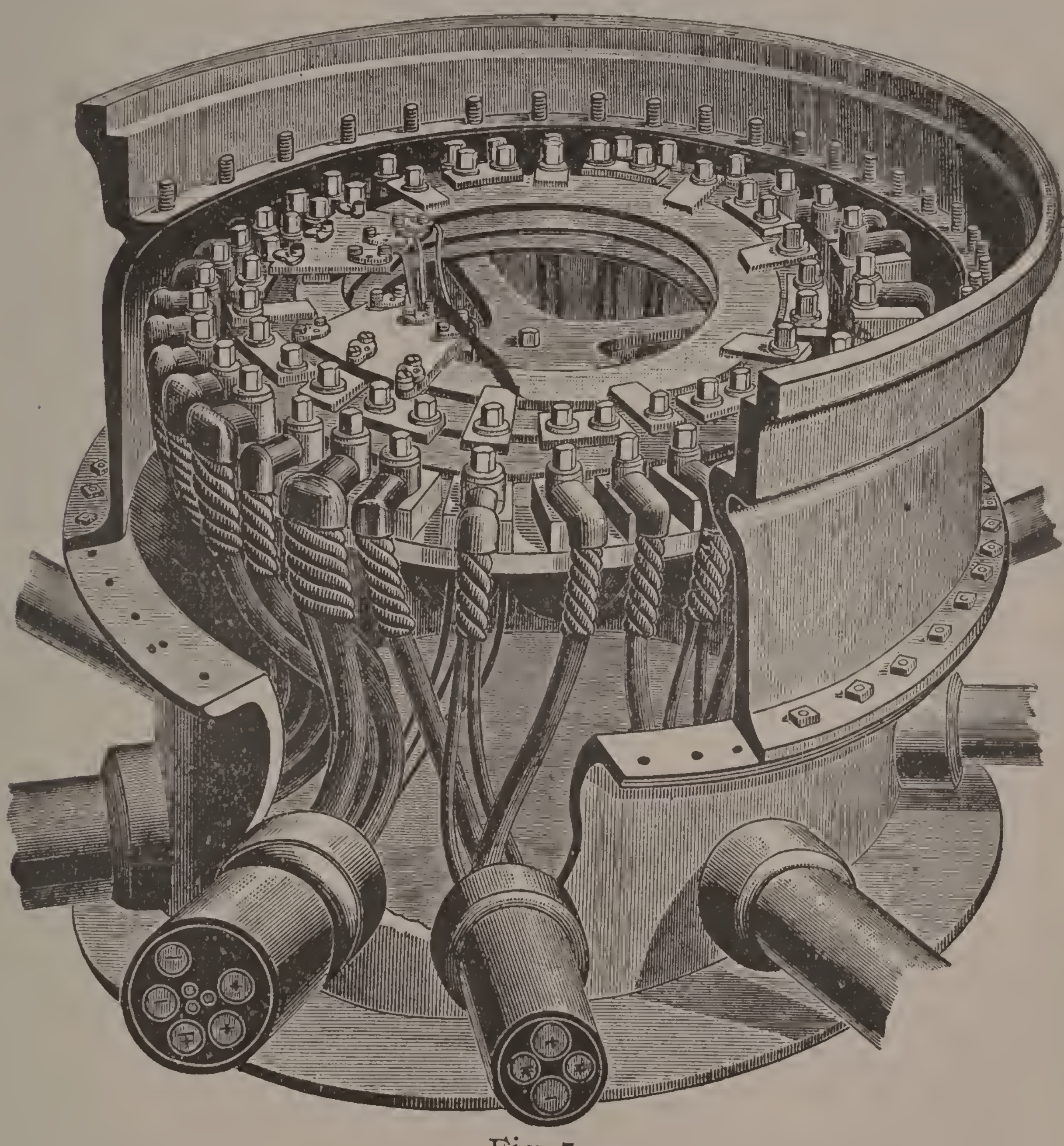


Fig. 7.

A level and uniform foundation should be secured. A sagging of a tube will cause the connecting joints to come together and produce a burn-out. This and a straining on a tube causes frequent trouble. A strain in a tube brings the copper conductors into contact with each other or the iron pipe.

Clean copper terminals are essential for good contacts and prevent undue heating. Above all, the plugs at the ends of the tubes must be scrupulously clean, as any slight accumulation of foreign matter may lead

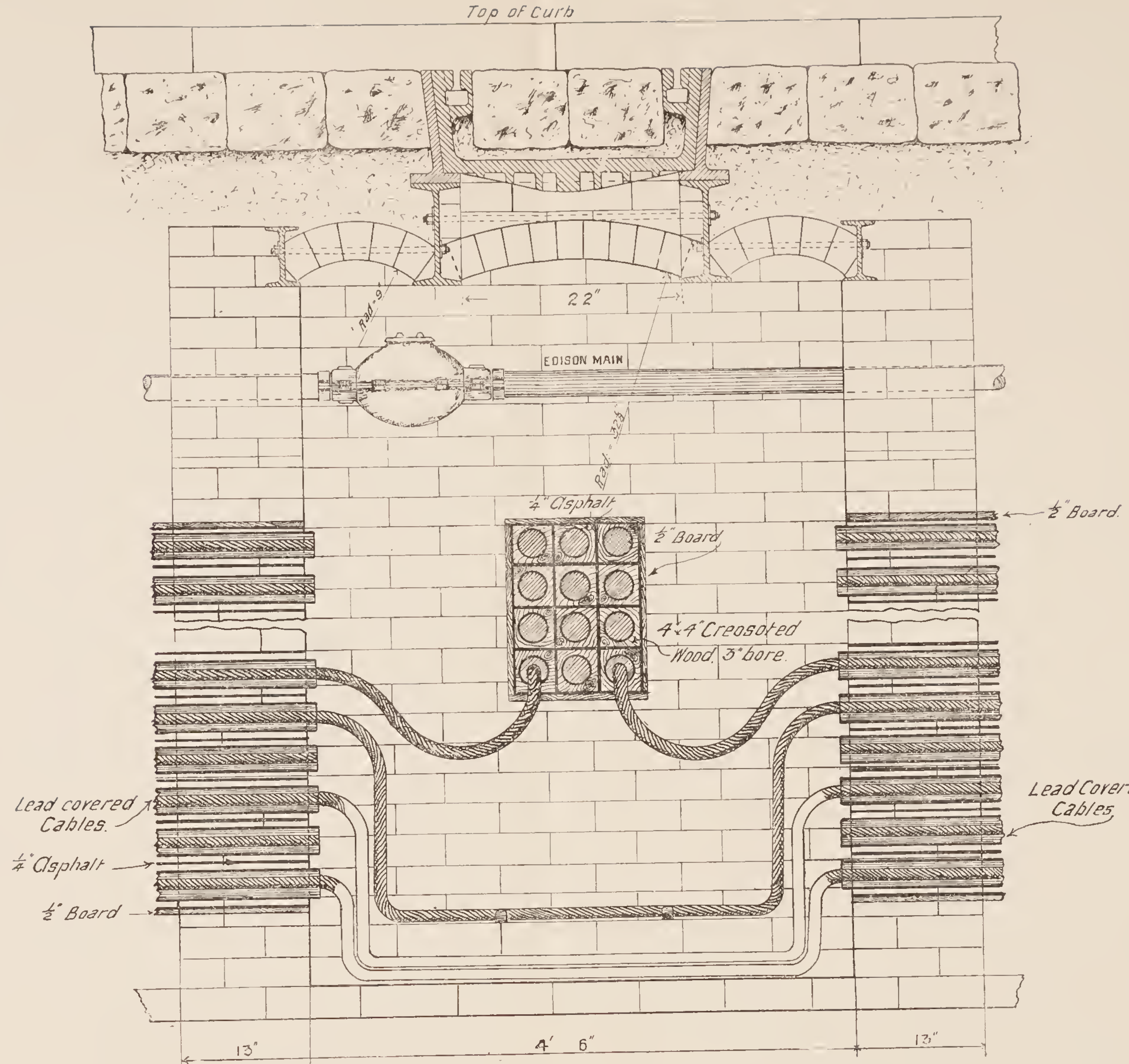
to a short circuit between the conductors. All joints should be well wiped and cleaned to insure that no loose solder can be heated by the insulating compound or the current, and allowed to run between the connections.

Proper filling of the boxes with the insulating compound is an important matter. Much trouble can be caused by water finding its way into the boxes, which after it reaches the joints, causes complete burn-outs.

Another source of trouble is caused by the irregularity in potential.

As a result of experimental scientific investigation, the following law has been deduced. "The tendency of the current to break through the insulation is directly proportional to the square of the potential." This means that if the voltage is 115, the tendency to break through the insulation is 115 squared, or 13,225 units. Now suppose the potential rises two volts, and is 117, a small rise apparently causing no damage, yet the tendency to break through the insulation is (117) squared or 13,689 units, a difference of 464 units for a two volt rise. If the voltage rises to 120, the difference will be 1175 units, or an increase of over 8 per cent. in the tendency to break through the insulation. As any log book will show, a majority of burn-outs do occur, not as might be supposed, during the time of heavy loads, but at the time of light loads and high voltage. That is, the most complete burn-outs on the street conductors develop between midnight and early morning, during the time when the load rapidly falls off and the potential naturally rises, unless the strictest vigilance and most prompt action is exercised by the dynamo room man controlling the regulating apparatus.

Given (Fig. 8) a wooden conduit, a cable feeder, an Edison main and junction box, you have (considering the items of compactness, cost and durability), the material for as good an underground construction as has been devised by man up to the present time.



LONGITUDINAL SECTION OF MANHOLE

ABSTRACT FROM A

LECTURE ON ELECTRIC HEATING

BY

A. E. KENNELLY, F. R. A. S.

By conducting electricity, a wire becomes heated. The energy which the heat represents, is taken from the circuit, and is, therefore, derived from the source of electro-motive force which is supplying the current in the circuit. In every case of electric heating, this heat has to be supplied from the circuit and by the source of energy, which in its turn supplies the current. An electric current, in fact, is only the distributing agent, and the energy is usually developed in a central station from the coal burnt under the boilers.

We measure power, or the rate of doing work, in watts. An activity of one watt taking the form of mechanical work, is equivalent to the performance of 0.738, or nearly ¾, of a pound raised one foot in height per second, but if the work be expressed as heat, then one watt may be represented by the heating of one pound of water about 1/18 degree Fahrenheit in one minute. It is important to observe that work cannot be expressed in watts, but only the rate of doing work, a horse-power being equal to 746 watts, or an activity of 550 ft. lbs. *per second.*

The heat produced in a wire only depends upon the number of watts expended electrically by the current in overcoming the resistance of the wire. The greater the resistance of the wire, the greater will be the number of watts expended by a given current strength in a wire, and tbe greater will be the amount of heat produced each second. If we divide the number of watts by 18, we obtain the number of pounds of water which could be raised one degree Fahrenheit in one minute by this activity, if entirely applied to that purpose.

If we measure the drop of pressure in volts which occurs in any length of conductor when it carries a current, and multiply by the number of amperes of current, we obtain the number of watts and we know

the amount of heat which is being developed in the wire. Thus, if a feeder connecting a central station with a net-work of street mains shows a drop of three volts, and carries a current of 600 amperes, there will be an activity of 1800 watts in the conductor entirely expended in heating the copper, and capable of raising one pound of water one hundred degrees Fahrenheit in every minute of time, if the heat could all be collected and utilized for this purpose. Although it is therefore very easy to thus ascertain how much heat is being developed in a conductor carrying an electric current, when the drop of pressure and current through that conductor are known, it is much more difficult to say what the effect of that heating will be, or, in other words, how hot a conductor will become, because it is very difficult to determine how rapidly the heat which is produced, will escape from the substance of the conductor into the air or surrounding bodies. If the conductor, as for example a wide ribbon of copper, offers a large surface to the surrounding air, then it is evident that the same amount of heat developed in the conductor; *i. e.*, the same number of watts expended in it, will not heat the ribbon nearly so much as a round wire of the same resistance and weight, since the round wire would not offer the same surface from which the heat could be set free. Not only the shape of the conductor, but also the nature of its surroundings have an important influence upon the heating of the conductor and the temperature which it will reach for a given number of watts expended in it.

In an electric stove or heater, where a high temperature is desired, a heated conductor is placed within a thermally non-conducting material and the flow of heat from the apparatus is checked as much as possible.

A copper wire carefully insulated, when immersed in water, by a thin coating of water proof material is usually kept comparatively cool, owing to the rapid conduction of heat through the insulating cover into the water. The same wire carrying the same current, but suspended in air, instead of being immersed in water, will usually attain a considerably higher temperature, as still air does not carry away heat from the surface of the wire so effectively as still water. For the same reason a wire buried under ground will, in almost all cases, be found to be cooler where buried in the ground, than where supported in the air of a vault. Consequently, if it be desired to know whether a feeder or underground conductor buried in the ground is overheated by a powerful steady current, it is only necessary to make an examination of the feeder where it is supported in the air in the vault before entering the underground trench outside the building. If the temperature of the conductor is not excessive in the vault it may in almost all cases be considered as not excessive in the ground outside, unless, indeed, it be buried near the surface and exposed to the sun's heat, or be buried close to a number of other conductors which are heated by powerful currents, so as to be unduly heated by their vicinity.

A wire which is not uncomfortably hot when grasped in the hand may be regarded as having a safe temperature; *i. e.*, a temperature incapable of either injuring the insulation of the wire or dangerously heat-

ing surrounding objects. A wire on the surface of a dynamo field magnet is similarly not dangerously hot when the hand can be borne upon its surface. The limitations to the heating of dynamo electric machines are, however, usually fixed by the number of degrees to which they will heat under continuous full load above the surrounding air. Thus, well designed modern dynamo machines are usually guaranteed not to increase in temperature above the surrounding air more than 40° *C.* or 72° *F.*

The Fire Insurance authorities adopted for the limiting current strength which a wire shall carry in buildings, a rule that is much below this limit, and corresponds to a temperature elevation at full load of about 10° *C.* or 18° *F.* which represents a temperature elevation of 40° *C*, under accidental continuous overload of 100 per cent; *i. e.*, twice the permitted current.

The property of the heating of wires by electric currents, although usually an inconvenient necessity, is utilized in safety fuses which consist of conductors, usually of lead or lead alloy, and which have a high resistance, so as to develop a comparatively large number of watts under a given current strength, and a low melting point, so that a comparatively low temperature shall melt them. By this means a safe current can be carried indefinitely through such a fuse without overheating it, but when a current becomes too strong for the circuit or the conductors in the circuit, the fuse melts and interrupts the current.

A wire of 500,000 circular mils, carrying 200 amperes will become considerably hotter than a wire of half the size, *i. e.*, 250,000 circular mils carrying half the current or 100 amperes, for the reason that it has much less surface for its weight than the small one. Similarly a safety fuse consisting of six lead wires rolled together into a strand will not carry six times the limiting current of each lead wire separately, owing to the reduced surface per wire through which the heat can escape into the surrounding air.

In a wire of uniform cross section, composed of copper, iron or german silver, the iron will heat more than the copper, and the german silver more than the iron, owing to the difference in their electrical resistance and the greater number of watts produced by a current in the higher resistance wires.

The heating effects of electric currents are commercially utilized in various forms of electric heaters for the smelting of refractory ores, in electric welding machines and in electric stoves or house and car heaters. By the electric furnace a higher temperature can be obtained than in any other way, and chemical products, such as carborundum, carbides of calcium and aluminum can be obtained, which it would be very difficult or perhaps impracticable to obtain by more purely chemical methods. An electric welding machine produces an enormous current strength, sometimes 40,000 or 50,000 amperes through the ends of the two metal rods which have to be welded together, and so enables their temperature to be very rapidly raised to the welding point. Railroad rails are sometimes welded together by this process, the power employed being about 200 kilowatts.

An electric heater or cooking stove finds considerable difficulty in

displacing existing forms of apparatus, because it is cheaper to burn coal in a stove than to burn coal under a boiler in order to drive an engine and dynamo for the development of electrical energy which shall be reconverted into heat in an electric heater. Since electric energy in small quantities usually costs about 15 cents per kilowatt hour to the consumer, the cost of raising one gallon of water from an ordinary temperature to the boiling point, allowing for the usual losses, is about 8 cents, by electric heater. Where, however, only a small amount of cooking or heating has to be done, the cleanliness and convenience of the electric method are greatly in its favor. Similarly soldering irons, flat irons, etc., can be heated electrically less cheaply but much more conveniently than by flames.

Explosives, such as submarine and subterranean mines, are usually exploded by the heating effect of an electric current in a fine wire or fuse situated at a distance from an electric source.

ELECTRIC METERS

BY

H. P. EDSON,

CHIEF OF METER DEPARTMENT.

In buying and selling it is necessary to have some basis for determining the prices which are to be paid. Most all goods are sold according to size, quantity, weight, etc. Guess work is not safe, and where values cannot be measured we demand averages based upon long experience. When it is possible to measure goods delivered the ingenuity of man is untiring until some means is found adapted to the use of all the trades of the world. It is only so far as we can draw from nature's limitless supply of necessaries and blessings—without money and without price, that we fail to find in these days a meter check upon our consumption.

As long as people live in civilized communities, water and artificial light, will represent somebody's labor, and as they come to be more and more generally used, they must be more and more accurately measured.

Perhaps it has never occurred to many of us that about the only system of measurement that has ever quite satisfied mankind is the method or device by which we reckon the passage of time, which doesn't cost us anything.

We look with suspicion on all forms of measurement. We know by the ticking of the water meter that it is away off of any standard. And we are positive that the gas meter as well as the man that reads it is a liar and a fraud, and everything else that is bad.

Now the electric current meter is a baby yet, but it is very likely to be considered by the majority of mankind as a direct descendent of the gas meter "a chip of the old block"—as it were.

There are a great many kinds of electrical meters and it would probably take me more than an hour to mention their names let alone their descriptions, I will this evening spend most of the time in describing to you the Edison Chemical Meter for two reasons.

First. Because the Edison Chemical Meter is the one and only one used by this Company for measuring the current supplied to its consumers.

Second reason is because I do not know enough about other styles of meters to spend more than a few minutes in describing them.

Mr. Edison knew, when he was working to perfect his system of incandescent electric lighting, that it was very necessary to have a cheap and accurate meter for the measuring of electricity. And a long series of experiments made by him culminated in the production of the present Edison meter, which is used very extensively in this country and abroad.

The meters which Edison made during his experiments will probably be interesting to you, but before showing them to you I wish to explain the fundamental principle of the Edison meter. We have here a jar containing two zinc plates immersed in a solution of zinc sulphate. The action of electricity in passing from one plate to the other through the solution is to cause the first or positive plate to be eaten away and the same quantity of metal to be deposited on the second or negative plate. The metal does not go across the space between the plates. The action is this:— A molecule of zinc sulphate solution is decomposed at the negative plate, and the zinc in this molecule adheres to it, while the other elements of this molecule seize upon the zinc in the molecule behind it, and form a new molecule. This action keeps up through the distance between the plates until the freed elements of the last molecule seize upon an atom of zinc from the positive or loosing plate. This action is very slow and entirely invisible, but extremely sure. Occasional cases occur where the plates are over loaded and cause granular deposit which is likely to fall off from handling, (experiment), it is not necessary, by the way to use zinc plates, copper, silver, gold and many other metals are affected the same way. The amount of metal deposited is exactly proportional to the quantity of electricity, therefore in the case of the Edison meter the most essential part of the prepartion of the plates is the weighing.

Faraday was guided by careful investigation to the conclusion, that when a current of electricity flows through a solution of diluted sulphuric acid, the amount or weight of the electrolyte decomposed is exactly proportional to the quantity of electricity that has traversed it. Hence if we catch for instance the bubbles of hydrogen which come off of the negative plates for any time, and weigh them the result will be exactly proportional to the number of coulombs of electricity that passed through the liquid. The weight measured in grammes of any constituent of electrolyte which is liberated by the passage of one coulomb of electricity, is called the "Electro Chemical Equivalent". Practically it is found that the best metals to use in measuring quantities of current are either silver, zinc or copper.

The Edison meter which we use in this station is shown here. The meter case is made of well seasoned hard wood, specially prepared to expel air and to prevent warping and to maintain a high degree of insulation. The door is of heavy sheet iron which is locked by a button through which is passed a lead seal.

The wires enter and leave the meter through holes in the sides or bottom. The interior of the meter is so wired (by means of shunts) that only $\frac{1}{975}$ part of the current passes through the bottle or measuring apparatus. So you see we do not measure all of the current but a very small fractional part of it. Some people therefore claim that if we make a slight error in the measurement of the fractional part we multiply the error by 975. So we do, but if the error is one per cent. in the fractional part the result or amount of bill will only be one per cent. wrong.

There are two bottles to each shunt—each bottle receiving the same quantity of current—only one is essential however; the other one is merely a check. One defect of the Edison meter is the failure of the terminal of the plate and the spring clip making a perfect electrical contact every time. This failure you can readily see would prevent the passage of the current through the bottle and consequently we would obtain no deposit on that set of plates.

This rarely happens however to both bottles at the same time so you see we can fall back on the other bottle. This defect of the Edison meter is always against the Company and never against the consumer.

Changes of temperature have no appreciable effect on the correct registration. Of course, as temperature rises, the resistance of the solution *decreases*, and would affect the reading were it not for what is called the compensating spool, which is a coil of wire inserted in the bottle circuit; the resistance of which *increases* as the temperature rises, and therefore balances the effect produced on the solution.

The solution which we use, freezes at a few degrees below the freezing point of water. If the solution freezes in a bottle, no deposit will take place. To prevent this there is made an instrument called a thermostat. It is placed in all meters that are exposed to temperatures sufficiently low to endanger freezing of the solution in the bottles. It is furnished as an extra attachment and space is left for its insertion in any size meter. It consists of a slender compound strip of brass and steel; one end of the strip is firmly fixed, while the other end, armed with a contact point, is free to move. A lamp is inserted in the socket—a high voltage lamp is preferable as it will not burn out so quickly. When the temperature becomes dangerously low, the brass contracting more than the steel, causes the strip to curve and brings the two contact points together, thus closing the circuit and lighting the lamp. The lamp burns until the temperature in the meter rises—the strip then strightens out, the contact is broken and the lamp extinguished. This lighting and extinguishing of the thermostat lamp, goes on during all cold weather at regular intervals, sufficiently frequent to keep the temperature of the inside of the meter above the freezing point of the zinc sulphate solution.

Now as the meter has been explained and its fundamental principles pointed out to you, let us see how a set of bottles or rather plates go through the various stages. When we receive the plates from the manufacturers, they are dirty and greasy; they are ground on a sand paper wheel to clean and brighten them. The copper rods or terminals are then painted with asphaltum varnish for about an inch, to insulate the

copper from the solution. If the terminals were not painted, we would have the copper and zinc in the solution, which you know would form an excellent battery, and the resulting current would interfere with accurate readings. Next the plates are amalgamated—that is, dipped in mercury which causes the plates to obtain a polished silvery appearance. The plates we use are not perfectly pure zinc, they may contain in some one spot a little iron or other foreign substance which would cause a current between the impurity and the zinc. To overcome this we amalgamate the plates, which causes them to behave as if they were made of pure zinc. They are now placed upon a rack to dry for a day or so, when perfectly dry they are ready for weighing. The scales used for this work are very delicate affairs and are capable of weighing down to 1/10 of one milligram, which is about the weight of an eye-lash. We find however, that five milligrams is sufficiently close for our work, as it means only five cents in the bill.

Each consumer has a sheet which is so ruled, that it will contain all the weights of the plates that go into his meter for a period of two years. On this sheet is recorded the weights of the set of plates (say four) which we are following. These plates are weighed a second time by another man, and records put down on another sheet, which are compared at the end of each day, and mistakes, if any, rectified. This system of duplicate weighing enables us to insist on the correctness of the bills rendered, as the weighing is the most likely place for an error to occur.

The plates are now ready to "put up," that is, connected together with other plates by means of hard rubber bolts, nuts, etc. One weighed plate with its mate is placed in a bottle—so we have four bottles, each containing two plates, only one of which, however, has been weighed.

The bottles are now filled up with the Zinc Sulphate Solution, the specific gravity of which is 1.054. This number tells us how much heavier it is than pure water. To determine the specific gravity we use an instrument called a hydrometer. (Experiment.)

The bottles are now corked up to prevent the solution from evaporating and from being spilled. Cards bearing the name and address of the consumer are then attached to each bottle. They are now placed in the meter and left there for four weeks. In placing the bottles in the meter it is necessary that the meter man make every effort to make a good electrical contact between the terminals of the plates and the spring clips. It is also necessary that he must seal carefully each meter, as some enterprising individual might be tempted to remove the bottles from the meter and thus save himself about half the amount of his bill. The bottles are placed in the meter in such a manner that two weigh plates gain and two lose. After having been in the meter the full term they are replaced with new ones, the old ones being returned to the meter room where they are "shocked out," that is, plates removed from the bottles, taken apart and put on the rack to dry. They are then weighed in duplicate as before, and the weights entered on the sheets opposite the weights of the same plates when they left the meter room four weeks previous. They are then returned to be ground, to go through the same stages for some other meter

the following month. Meter plates in ordinary practice last from eight to ten months when they are consigned to the scrap pile.

Now as to the manner of computing the bill from this set of plates—we will suppose they were the smallest size plates and the weights were :

	Outgoing.	Incoming.	Diff.	Average diff.	Lamp hrs.	Amount.
A.	35,000	34,500	500	500		
B.	35,000	35,500	500			
C.	35,000	34,500	500	500		
D.	35.000	35,500	500	1000	1782	$13.37

The average difference on each side is 500 milligrams, or a total 1000. In practice the gaining plates always gain a trifle more than the loosing looses. This is due to what is called oxidation, which is the deposition of some of the zinc in the solution upon the plates, causing them to gain in weight. This oxidation takes place upon the plates whether they are in a meter or whether they are not, so long as they are immersed in the solution. The factor of oxidation does not affect our calculations, as we have two loosing and two gaining plates. Considering oxidation, the returns would be as follows :

	Outgoing.	Incoming.	Diff.	Average diff.	Lamp hrs.	Amount.
A.	35,000	34,520	480	500		
B.	35,000	35,520	520			
C.	35,000	34,520	480	500		
D.	35,000	35,520	520	1000	1782	$13.37

You see that the loosing plates gain the same weight due to oxidation that the gaining plates do, and to eliminate this factor of oxidation, we place the bottles in the meters in such a manner that two weighed plates will gain and two will loose.

As to the accuracy of the Edison Meter, I can say that I have tested some two hundred meters, and none of them were more than two per cent. wrong, and I noticed that in nine cases out of ten, the readings were smaller than they should have been—showing that the Edison Meter generally reads low. All carelessness, whether in the Meter Department or on account of dirty clips, or of bottles being frozen, causes the bills to be smaller than they should be, and the Company suffers—not the consumer. Probably some consumers will not believe this, but it is a fact nevertheless.

The Edison meter stands on its own merits ; It is more largely used to-day than any other style ; its accuracy is unquestioned by any person who knows anything about meters. It is somewhat large but quite a cheap meter to operate. It has a great advantage over other meters in the matter of first cost, and it will stand rough usage very well—A damp cellar or an occasional shower bath, or a ton of coal being dumped on it, will not affect its accuracy.

There is not much about it to get out of order and repairs amount to nothing ; while the double bottle system and the fact that we start fresh every month insure perfect readings and accurate bills.

Nevertheless we have some complaints from our consumers about the size of their bills. Some write letters asking us to guess again. Others have an idea that the bills are derived by multiplying the number

of lamps by the number of dark days in any one month. And when we start to explain the Edison meter—they claim that the meter is only a bluff, and if they don't kick their bill will keep on increasing until they do, so they think it advisable to make a complaint about every six months.

Other devices for the measurement of electricity have been tried by a great many experts, but no instrument has been found to combine in so high a degree the indispensable elements of cheapness and accuracy. All other forms of meters yet produced may be said to be either commercially impracticable or capable of only limited application. They are almost, without exception, too delicate or too costly for practical use, while being at the same time liable to a considerable error from frictional, magnetic and other variations. The principle of an ordinary electric motor enters into some of the most successful electricity meters. The quantity of current passing through such a meter determines the speed of its parts, which is registered on the dial either in Ampere hours or Watt hours

One form of mechanical electricity meter, which we have here is a meter which measures the magnetizing power of the current, but as this is proportional to the current it also may be said to measure the current. The current passing through a coil causes it to become magnetized. This magnet attracts and holds a pendulum on the end of which is a piece of iron. The pull or force necessary to detatch the pendulum from the coil is measured and is recorded on the dial in Watt hours. This measuring takes place about every two minutes, and is found to be fairly accurate but quite complicated.

Another very interesting and ingenious meter has the following principle involved :—A circular disk is caused to rotate very slowly by means of a small electric motor—at right angles to this disk is a rod on the end of which is a wheel connected to the dial and in contact with the disk. When there is no current passing through the meter the disk is stationary —but as soon as the current is passed through the disk starts to rotate— the speed is same for all loads. The rod to which the dial wheel is attached is moved up or towards the rim of the disk as the current increases, by means of coils through which the main current passes. Thus it will be readily seen that the speed of the dial wheel, will depend entirely upon the distance it is from the center of the disk.

DYNAMOS AND MOTORS,

BY

C. BILLBERG,

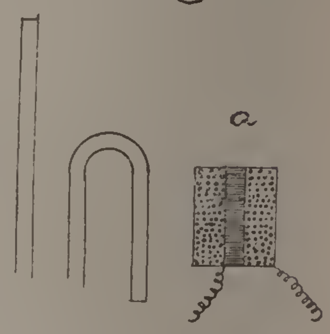
ELECTRICAL ENGINEER.

As time is very short I will leave out entirely all history and confine myself to fundamemtal facts and principles underlying the construction of the modern Motor and Dynamo.

The first thing we must try to make clear for ourselves is the phenomenon of magnetism. You are all familiar with the picture we get if we take and dip a magnet into iron filings. If we examine such a picture closely, we will see that, though every time we dip the magnet in, we get a somewhat different looking bunch, there nevertheless are certain features common. The filings seems to form more or less threadlike lines. In fact, if we draw a line through the centre of each one of those small iron particles from one to the other, we will find, that that line commences at one pole of our magnet and proceeds through an easy curve to the other and we may consider that, at the point where our curve strikes the magnet it enters it and continues through the magnet to the place where we started; thus forming a closed curve comprised partly within the magnet and partly in the space outside of it. This gave rise to the idea that the magnet was surrounded by such lines or curves at all times (entirely independent of the filings) and that though invisible they are there. In fact we find that a small magnet needle sets itself in the direction of the lines passing through that point and we can, by allowing such a small needle to move, trace curves representing those lines. As those lines are a most convenient way of forming a mental picture of the action of a magnet it has been universally accepted. Those lines or curves are known under the name of Lines of Force. This expression is now extensively used and we have even instruments by which we can measure the quantity of such

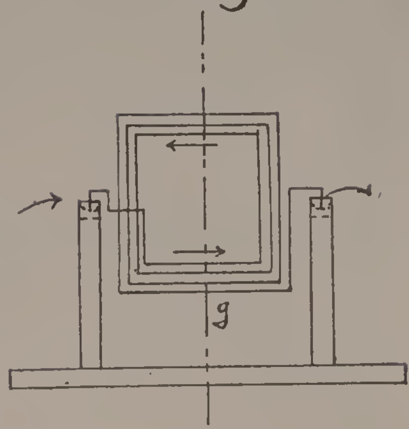
lines per square inch. The space wherein such lines are found is called a "Magnetic Field". It might be well to state here that we do not have any material that will do for those imaginary lines, what our common rubber or porcelain insulators will do for Electrical currents, or in other words, we can not insulate for magnetism.

Fig. 1.



I have here a coil of insulated copper wire and if, I now put this straight piece of soft iron in it and then send a current through the windings of the coil, you will see that it behaves, relatively to the iron filings, in the same way as the magnet; in fact, it is a magnet and similar curves through the center of the fillings can be traced just as we traced them in the case of the magnet and those curves have the same properties as those of the magnet. If I now, when the filings still cling to the iron, cut of the current, we will see, that the iron filings will drop, but be attracted again the moment I close the circuit and allow the current to flow. This shows that we must continually supply the coil with current or energy in order to be able to make use of this force. Now if you notice the bunch or number of filings clinging to the end of the rod and compare them with the bunch which will hang on to the rod I now substitute and dip in the filings, you will see, that by substituting this horse-shoe form of rod, the bunch or number of filings has considerably increased, though, as I said before, the current or other conditions are the same in both cases. If we could trace the curves from those filings we should see that they, or the number of lines of force, would be largely increased. If we substituted a rod of cast iron instead of this one of wrought, we would see that the number would decrease and this gives us means to determine the quality of the iron; the more such lines of force we can drive through a piece of iron with expenditure of the same amount of energy, the better is that iron fitted for magnetic purpose. If we once more take our coil, sending the same current through, but leaving the iron out and try to attract the filings we will see a very slight action but still some. This proves that the force is emanating from the coil and not from the iron but that the iron increases this force. There are only a few known bodies such as iron, nickel and cobalt, that have this property. In fact iron has for the magnetic lines of force this property in a very high degree. The difference between iron and air, or copper, can sometimes reach such numbers as 20000, which means that through one square inch of iron we can send 20000 times as many lines of force, as we can send through one square inch of air or copper with expenditure of the same amount of electrical energy. As we can not get chemically pure iron and as it is a fact that a fraction of a per cent. of impurities, sometimes changes this value very much, for instance 12 per cent. of manganese brings the carrying capacity of the iron almost down to the level of air or copper, the importance of knowledge of the iron we use for magnetic purposes is very great. It also follows from this that the make up of the magnetic circuit is of utmost importance in all cases.

Fig. 2



I have here a coil or wire suspended, in a vertical position on two points in mercury cups. As one point is connected with the beginning end and the other with the ending end of the coil, I can pass an electric current through it by those means. If I now send a current through this coil of wire and if I then bring this coil of wire (the same I used before (see Fig. 1) through which I also have a current flowing) near to it, we see that the coil moves a little bit, but, if I now put in this piece of straight iron in the coil, without changing the amount of current flowing, we will see that the deflection of the vertical coil is somewhat larger and increases still more if I exchange the straight rod for this horseshoe formed one. Fig. 3 is an end view of same coil as in Fig. 2. Letter (*a*) represents our electromagnet in position and (*b*) our movable coil before current is turned on. Line (*c*) represents the position of coil (*b*) when current is on both coils but no iron in electro-magnet (*a*). Line (*d*) represents position of coil (*b*) with straight bar inside coil (*a*).

Fig. 3

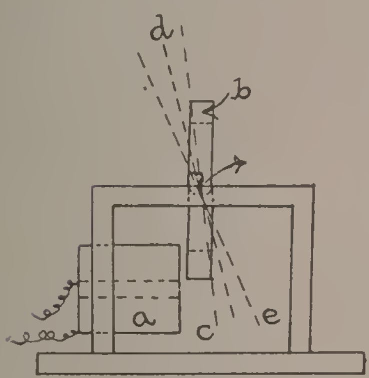
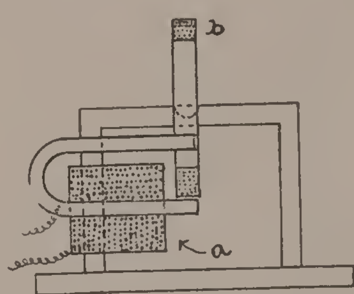


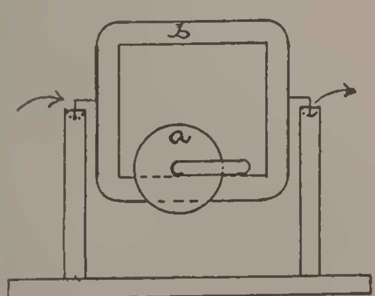
Fig. 4 represents a cross-section (through line (*g*)) of Fig. 2, including electro-magnet (*a*) with horse-shoe formed iron in place. Line (*e*) Fig. 3 represents deflection of coil (*b*), when current is flowing in both coils and horse-shoe-formed iron piece in place.

Fig. 4



In all those cases we see that our lines of force due to the coil (*a*) *cause* more and more movement of coil (*b*), as we increase them by making our magnetic circuit better and better and thus get more lines of force, without expending more electrical energy. We also see that our lines of force are cutting or crossing the wire of our coil (*b*) more or less at right angles. If we place our coils as is represented in Fig. 5, and turn on the currents, we will see that we get no motion and also, that the lines of force in this case are parallel to the plane of the coil (*b*) and not cutting it, as was the case in Figs. 3 and 4. We might also establish another fact and that is, that, if I decrease the current flowing through our coil (*b*,) we will see that the deflection also decreases.

Fig. 5

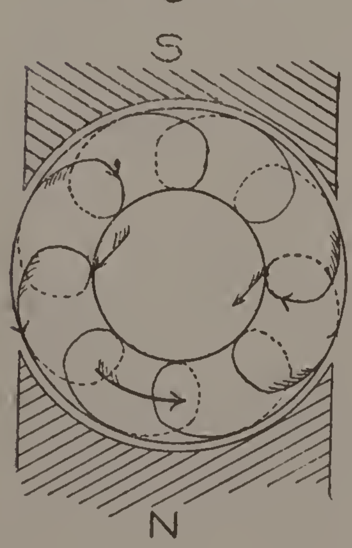


Those are the actions and reactions, which take place in the motor. That is, if a current flows through a wire in a magnetic field, the tendency is to move the wire carrying the current one way or the other, depending on direction of current or of field, if the direction of the wire and the lines of force are not parallel. In a similar manner, if we have same field and same wire, but instead of furnishing it with

current we supply it with motion, the tendency will be to set up a current in the wire. This action takes place in the dynamo, and as I can not show it to you by experiment very readily, you will have to accept it on faith. This reversibility of a phenomenon is met with quite often in nature and when we can produce it, it proves generally that we have reached a reasonably true idea about the subject in question. Before we leave our simple loop and electro-magnet I like to call your attention to another point and that is that we can predeterminate the way our coil is to move and by simply reversing the poles of our magnet, that is change the direction of our lines of force, we see, that the coil moves the other way, but, again keeping the electro-magnet or direction of the lines of force as we had it last, if we now reverse the current by changing connections, we see, that the effect is the same, or that the coil moves in opposite direction, that is in the same direction as in the first case. Of course this action is limited to a certain angle and if we want to produce continous motion we must supply means whereby we can either bring new coils into play or move our electromagnet. As the electromagnets are generally too heavy to be easily moved we must provide new coils at certain intervals and automatically change the currents in them, when the *action* so *requires.* In all those experiments with this coil (b) I have only used one side of it, but of course there is no reason whatever why we should not use the other side just as well only we must remember that if the current goes in one direction in this lower one, it goes in the opposite in the upper one and therefore must either the wires move in the opposite direction, or the lines of force. With those facts in mind, the problem to be solved, was how to get continuity of action. The best solution of this problem is effected when the coils are mounted on a shaft, concentric with which the electro-magnets are arranged and when instead of keeping each coil separate for itself they are all connected in an endless coil to which current is fed from two diametrically opposite points in case of a bi-polar machine, with which arrangement continuity of action is gained.

In order to make this clear for ourselves, let us consider how the currents would flow in such a structure. Let the Fig. 6 represent an endless coil of bare wire, bent in the shape of a circle. Select two diametrically opposite turns, so situated that we have just as many turns on one side of this diameter as on the other. Make the connections and allow the current to flow. As we have the same number of turns on each side of the contact or brush where the current is supposed to enter and as those turns are supposed to be of the same wire, length and electrical resistance, the current will divide equally, as there is no reason why more of it should go one way than the other, and the current will follow the turns as marked by the arrows. By mounting this coil on a shaft and surrounding it with a magnetic field, we can, from our previous experiment, say that we can produce

Fig. 6.



motion, because our wire, carrying currents, is placed across the path of our lines of force. As the current in both branches flows in opposite directions, and, when the coils rotate around their *axis*, the directions of motion in the two halves being also opposite, the tendency, with lines of force stationary, is for both halves to assist each other in the effort to produce motion.

In another way of looking at it we may say that, as the current follows the arrows, it creates poles and each branch produces poles of the same kind, because both current and direction of winding are opposite in the two branches, and results in an effect of the same kind as if we simply had, side by side, two steel magnets with the same poles turned in the same direction. If we now, keeping our brushes stationery, move the ring so that the brushes rest on the next two convolutions, we see that new poles have been created, but that their *places* in space *are* unchanged. This insures continuity of action.

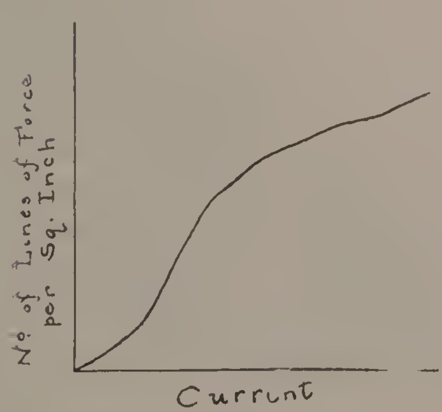
The part of the practical machine, which takes care of this changing the direction of currents in the coils, but keeps the poles stationary in space, we call the commutator.

If we remember, that a current, flowing in a coil in the direction the hands of a watch move, produces, looking down on it, a south pole, we can determine in which direction our coil is going to move. Following this rule and denoting with (s) a south with (n) a north pole, as marked on Fig. 6, our coil will move in direction, marked on same Fig. 6, of arrow as always two equal poles, (south and south) repel, and two unequal (north and south) attract each other. As we just now have seen, we can in this manner produce continuous motion. As this is true, so is also the reverse of it true, or if we supply motion and magnetism, we will produce electricity.

Before proceeding any farther, it might be well once more to call attention to the fact that, in order to make a modern machine of our imaginary one, we could not afford to have the lines of force pass through air all the way from one pole to the other and for that reason we would have to put, inside of our coil, rings of soft iron, which would offer an easier path for the lines of force and thus reduce the resistance of the magnetic circuit.

I might mention here, how we can compare different magnetic circuits in regards to their resistances. The simplest way is to use a fine wire of Bismuth, wound in a spiral. Bismuth has the property, that its electrical resistance increases in certain proportion to the number of lines of force, which go through it. Surrounding some part of our magnetic circuit with a coil of wire and sending varions currents through the coil, we measure the electrical resistance of our bismuth spiral for each current. From those data we plot a curve, which will have a shape, something like Fig. 7. The shape of the curve shows that the larger the number of such lines we want to drive through the same space the larger the force we must expend. Such a line or curve rep-

Fig. 7.



resenting the behavior of the magnetic circuit of a Motor or a Dynamo gives the constructor valuable information and is used for that purpose.

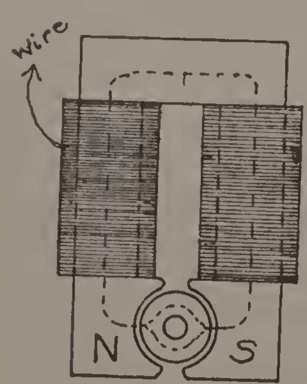
As we now have seen how we can produce electricity by machines, I will state here one of the most important electrical laws namely, the one that is known as OHM'S law. It says that, in continuous current circuits, the current (amperes) flowing through those circuits, no matter how complex they are, is directly proportional to the "Electro-motive force," "Potential" or "Volts" and inversely as the resistance or "Ohm's" of those circuits; or to use mathematical language:

$$C = \frac{E}{R} \quad \text{or} \quad \text{AMPERES} = \frac{\text{VOLTS}}{\text{OHMS}}$$

That simple law is almost the key to all continuous current problems and for that reason a most important one.

The laws and experiences just recited, constitute the fundamental principles necessary to produce a modern machine. To go into detail of the mechanical construction seems unnecessary as we are all familiar with them. I may say that, from the geometrical shape, the armatures have been classified in RING, DRUM or CYLINDER and DISC. The theoretical principles are exactly alike in all of them and the difference lies only in the mechanical construction. Nearly all armature cores of the present day, are made up of thin rings or discs of soft iron insulated more or less from each other, strung on a shaft or bushing and securely clamped or riveted together. Most of the modern ones have their wires or bars imbedded in the iron, in order to reduce the magnetic resistance to a minimum. The reason why toothed armatures have not been in so general use heretofore lies in the fact, that the teeth, when they revolve in front of a pole piece, produce wasteful currents in the mass of the iron, causing excessive heating and waste of power. Various ways to prevent this loss have been devised and are used. By making the number of teeth large or, what means the same thing, making the grooves deep and narrow, together with proper distance in the air gap or space between armature and pole pieces, they are overcome to a certain extent. Of course if we laminate the pole pieces themselves, or lay our wires in grooves with narrow openings in the armature surface or put them entirely under the surface, or if we wind over the whole outside surface of the armature a layer of iron wire concentric with the shaft, we can obviate this loss and reap the benefit of the better magnetic circuit. The armature is, as a general rule, the movable part of the machine and the field the stationary one. Of all parts of the modern machine the field is the one that is met with in the most variable shapes. I have here in Figs. 8, 9 and 10, some of those more generally seen in practice. Fig. 8 represents a bipolar type generally known as the Edison. It is found in all possible positions such as standing on the pole

Fig. 8



pieces, on the yoke, lying down on the magnet limb and others. It has a single magnetic circuit in the field, and as usual in bipolar machines, it has a double one in the armature. We see, from Fig. 8, that the magnetic lines of force, due to the current in the field coils, follow closely the mechanical construction of the iron part of the machine, a very commendable feature.

Fig. 9 is also a bipolar type known under the name of Manchester. The same remarks as made over the Edison type, hold good for this, with this difference, that we here have two magnetic circuits in the field instead of one, which for motor purposes has certain advantages because of the greater constancy of the field against variation in potential and therefore greater constancy of speed.

Fig. 9.

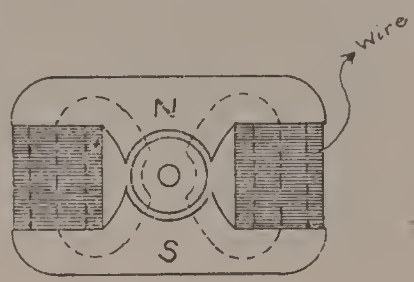


Fig. 10.

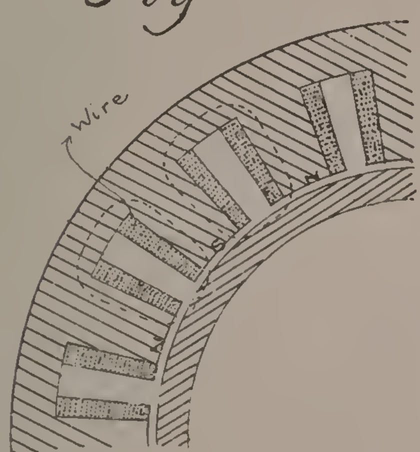


Fig. 10 represents a part of a Multipolar machine frame, as we mostly see it in practice. The same can be said of this type, as has been said of the two previous ones. It has, if we consider each pair of poles as a unit, a double magnetic circuit like the Manchester type. As a general rule it can be said, that the magnetic circuit must, as much as possible, follow the curves of the lines of force, and that any serious deviation is apt to lead in the wrong direction.

This small motor however, is a good illustration of the fact that it may sometimes appear advisable to sacrifice some of the efficiency for the sake of neatness in appearance, convenience in manufacturing and cheapness generally.

As we all realize, both motors and dynamos are simply means for transferring, the first, electrical energy to mechanical, and the latter, mechanical into electrical. In either case it is of importance to clearly understand the relation between electrical and mechanical units.

We all know that work is done when a weight is lifted to a certain height, or that the product of weight, measured in pounds, and the height measured in feet, to which the weight has been lifted during this unit of time, gives us a measure of power and we say that one Horse-Power (we will in the future designate horse-power H. P.) is equivalent to 33000 foot-pounds per minute, and this constitutes our practical unit of power and means that one H. P. has been expended or stored up, when we lift during one minute, one pound 33000 feet high or 33000 pounds one foot high during the same time. It is entirely indifferent whether we lift one pound or any number of pounds to a given height measured in feet, provided only, that the product is 33000, we have used up work to the amount of one H. P.

The practical unit of electrical pressure corresponding to unit of of weight (pounds) is called VOLT, In the same way the practical unit

of current, corresponding to height or feet is called AMPERE, and the product of those, sometimes called VOLT-AMPERE, or also WATTS is the electrical unit of power corresponding to foot-pounds. As work or power must be the same, independent of the units chosen, we will have to remember, that one H. P., 33000 foot-pounds or 746 Watts, all per minute, are different names for the same thing. This gives us means to convert mechanical units into electrical, and *vice versa*.

We very often hear people say, that so and so many Amperes is one H. P., but that is of course incorrect and really does not mean anything before we know the pressure, potential or volts producing the current. First by multiplying this number of volts with the current and dividing with 746 do we get at the H. P.

I have not said anything regarding another way of measuring work, as it probably has been told to you before. I may, however, remind you that work is also expended by increasing the temperature of a body and is generally measured in heat units. One British heat unit, that is the quantity of heat required to raise the temperature of one pound of water in one second one degree Fahrenheit, is equal to 772 foot-pounds per second. As we know before that 33000 foot pounds per minute or 550 foot-pounds per second is equal to one H. P. or 746 watts, we can figure out that one British heat unit is equal to 1047 watts per second.

As I said a little while ago, motors and dynamos are only means for transforming energy of one form into another, and, as we find all over in nature, such transformation is always accomplished only by wasting or using up a certain amount of this available energy. The transformation of electrical into mechanical energy or *vice versa*, is really from that standpoint, very good, as we do build machines giving an efficiency as high as 97 per cent. that is using up only 3 per cent. in effecting the transformation. If we remember, that we will loose from 3 to 8 per cent. in a belt only, we see that such a figure is quite remarkable. Of course the smaller the machines are the harder it is to keep the efficiency high, but still, we can to-day buy in open market a 2 H. P. motor or dynamo, with a guaranteed efficiency of from 80 to 85 per cent.

In order to gain such figures as mentioned above, the greatest care must be taken. The most important and unavoidable losses can be said to be divided into:

FRICTIONAL, such as bearings, air resistance, brushes and others.

ELECTRICAL, heating of wires through which a current is flowing, due to the resistance of the wire.

MAGNETICAL, due to leakage, hysteresis and eddy currents.

How to bring those losses down to a minimum belongs to the Electrical Engineer, but as general rules, it can be said that:

BEARINGS, ought to be well in line and provided with abundant oil supply.

ELECTRICAL resistance of armature as low as possible, resistance of field-circuit, if a shunt-machine, as high as possible, if a series-machine as low as possible.

ARMATURE--PLATES, of soft thin iron and, if provided with teeth means to prevent wasteful currents in pole-pieces.

Most of those losses will appear as heat, but it is far from true to say, that because a machine is hot, it is not economical. In fact one machine may be quite warm and still have a very much better efficiency, than another machine, which runs cool. This may be accounted for by the fact, that the temperature of a machine depends not only on the quantity of heat generated, but also on the heat dissipated.

As a final conclusion the following rule of thumb may be given : the slower a machine gets up to its final temperature, under given load, the better is the efficiency of that machine.

In the brief time allotted I have, as I stated in the beginning, confined myself to fundamental principles and facts and necessarily not touched on how to make motors and dynamos, but tried to give you an idea of some of the rules and conditions, that ought to be found in good modern machines.

FINANCES OF ELECTRIC LIGHTING.

BY

WALTER H. JOHNSON, Secretary.

The designation and use of finances, as understood to-day, began in the 13th and 14th centuries. It was about this time that the words "*Finare*", to pay a fine or subsidy and "*Financia*," payment of money, were employed principally by French writers to denote those bargains by which the indefinite liabilities of ancient holdings of lands or buildings were commuted for fixed sums payable to the immediate lord of the tenant.

The word "Finance" is derived from the above words "Finare" and "Financia" and "Finis", end; and Webster tells us that it means "The income of a ruler or a state."

Owing to the confidential nature of my position, I am somewhat embarrassed when discussing the income or finances of the Edison Company of Philadelphia, and can merely allude to some points or talk in the abstract, the details of which would probably prove most interesting; I shall therefore confine my remarks more to general business principles, the financial department, our system of keeping accounts and looking after the finances, and shall endeavor to avoid the usual dryness of statistical talk by the use of the conversational rather than the oratorical style. I shall endeavor to show you how carefully the expenses of each department are kept, the result of the work of the men in each department, watched from month to month, and the expenses of maintaining each department.

Profit is the gravitation law of the industrial world, and corporations, like individuals, should ever be looking into their resourses and expenses.

The art of saving is as necessary for corporations to learn as it is for individuals, and the old saying "Take care of the pennies and the dollars will take care of themselves" is not only a very true one but very applicable to Electric Light business where your profits are the 1/8 of a cent saved, and you have to keep down the price of selling your product or current to meet the price of $1.00 gas; or so near to it that your customers prefer paying the small increase for the better, safer and more healthful elec-

tric current. This remark applies more to the business portion of the district, where the business man is watching every penny of expense just as much as the management of the Electric Light Company is. At his house it is somewhat different; there, it is considered more in the nature of a luxury and elegance, together with the elegant opportunity for decorative effects, especially on special occasions; hence the cost is not so much a factor if the business is making money; but at the store it becomes a more potent factor of expense, and must be more carefully guarded.

Then, we have the isolated plant to guard against. The price of current must be kept so low that it would be unprofitable for a customer to put in a plant and manufacture his own electricity; and even remove the thought of an isolated plant as far from his mind as the installation of an independent gas plant is now.

By not keeping a correct and careful account of every expense incidental to the running of an isolated plant and all the pros and cons, there are some who think that they are saving money by manufacturing their own current; but I shall discuss this subject later on, and merely introduce it now to emphasize the necessity of closely watching expenses, thus producing the light cheaper and enabling it to be sold cheaper.

By way of illustrating the immense growth in finances of electrical enterprises, I collected the following data.

August, 1882, the first Edison Central Station was installed at Appleton, Wisconsin, with a capacity of 250 lights and driven by water power. The Pearl St. Station, New York City, was under construction at the same time, but it was not started until three weeks later; it was however the first station in the world to distribute current for incandescent lamps by a comprehensive system of underground conductors.

Then followed the Sunbury, Penn'a., Station, July, 4th, 1883, with a capacity of 500 lights; and was the first Central Station to adopt the three-wire system and to use the Edison Chemical Meter commercially. The first three-wire underground system was laid in Brockton, Mass.

A few weeks ago I read that there is now invested more than $800,000,000 in commercial applications of electricity, and that these figures are being increased by $100,000,000 annually, showing a most wonderful increase in about 14½ years.

This is truly called the "Age of Electricity", and the degree of commercial success of this new force is only limited by the ability to produce and to distribute it cheaply.

As stockholders invest their money for profits and not for scientific experiments, the industry must be worked so as to create a profit, and every man connected with the Station and office has the opportunity to enhance the ability of the Company to continue to give him employment by increasing his intelligence, skill and efficiency; and aiding in every degree of profit produced. You also prepare yourself for promotion, and what better example do you wish than the present Board of Control, every member of which has risen from the ranks to their present position.

The time is sure to arrive in the affairs of large concerns, when the directing Head must depend on others to some extent.

I speak of this, as it seems to me very pertinent to the subject of successful financiering of Electric Light and other Companies; and by this I mean the result, which is profits earned. This is not possible with figure heads in charge of the different departments, with a lot of supernumeraries around them half employed, so as to add to their importance and the "dignity" of their position. Then again, the disease is contagious, it passes all down the line to the office boy, or the lowest grade of employment in any department, and there is general apathy if not indolence all through the Company; hence the possible profits are consumed by the ⅛'s of a cent expenses.

Success requires conscientious, honest and faithful, as well as efficient hardworking Officers and Heads of departments, just as much as the rank and file of the men. It also requires eternal vigilance and uniform courtesy in all departments; and it is every man's duty to employ himself to his full capacity, as best he can.

In speaking of courtesy, I am reminded of a little experience I had some years ago, when the Company was first started. A customer made a complaint that a fuse had blown; unfortunately the inspectors were all out and probably a half hour had elapsed, when the customer walked into the office again and was extremely abusive, would listen to no explanation, and finally became personal in his abuse. What followed you can imagine. I reported the case to the then General Manager and Supervising Engineer. Aftering hearing what I had to say, he solemnly pronounced the verdict, "Not guilty," but don't do it again." This man is still a customer and a profitable one; but many a dollar is lost to a Company by impoliteness and harsh treatment of customers, and the reverse is true,—many a customer saved by polite treatment when he has "blood in his eyes".

When taking up the different accounts, it was my intention to make comparisons between the four largest Edison Illuminating Companies; but owing to the different methods of keeping accounts and charging expenses, I abandoned the idea, as this information could only be gathered by a careful analysis of their books, which of course is out of the question.

As an example of what I mean, I will take only one item "Coal account". In Philadelphia we charge to this account the cost of coal at the mine, freight, storage in yards, hauling to Station, ashes from Station, wages of Coal Passers, Water Tenders and Superintendence, as well as labor, cleaning, boilers, and all repairs to them as far as the main line valve; material used, and even the repairs to elevators and wagons, as we consider them a necessity merely for the coal. In other words, whatever expense is incurred, directly, or indirectly in the production of steam, is charged to coal account.

Through the courtesy of the Vice-President and General Manager of a large Edison Station, I learned that when buying coal by cargo, all expenses such as the coal, freight, insurance, cost of unloading, repairs to bins, etc. are charged to "stock fuel". The coal is served out to the

Stations as required, at a price fixed every six months or so, this price being intended to leave no profit or loss whenever stock is taken of the amount on hand. Of course, there is always a small profit or loss, since all the expenses cannot be exactly forseen ; but the price is arranged to keep it as small as possible. This coal is served out to the Stations as required, and coal is also bought in small lots from dealers. This operating expense is charged to "Coal". If it is carted from a dealer, or from the bins to a Station in another part of the City, the cost is charged to "Carting coal". The expense of loading the carts and weighing the coal at the bins, and of loading the coal into the Hunt conveyer, which carries the coal into the 3rd Station, is charged to "Labor of fuel". The cost of carting away ashes is charged to "carting ashes." These four accounts, being the whole coal expense outside the stations, make up the "Operating fuel" account.

Inside the Station, any expense of handling the coal to in front of the boilers is "handling coal," firing it is "firing coal" and cleaning, sweeping, etc. is "cleaing in boiler room."

Any work handling ashes is charged to "handling ashes". Pay given to men while sick or on vacation is charged to "Sickness and vacation", and one or two of the foremen charge some time to "Superintendence in boiler room." These seven accounts make up "Labor at Station, boiler room."

Any labor done by the men repairing boilers, and all material bought for repairing them or work on them by outside parties is "Repair and renewal boilers". These are, I believe, the total expenses connected with coal.

The Philadelphia Edison Company has a capital of $2,000,000, of which there is paid in $1,847,222,22. Of this amount, $1,450,568,52 was spent in Property and Construction accounts, such as Furniture, Building, Machinery, Electrical Apparatus, Electrical Conductors, Services, Meters, Steam, Water and Blast Piping and Workshop Equipment.

A considerable amount of this (nearly one half) was spent in Electrical Conductors, as we were compelled by Councils to put our wires under ground.

The cost of future repairs was borne in mind by the Supervising Engineer. hence a solid, substantial building was erected, and everything done to avoid the usual heavy expenses of repairs ; and our books to-day show how well this was done ; for, considering that we work on the principle "An ounce of prevention is worth a pound of cure", and do not wait until something has become absolutely bad before making repairs, our repair accounts are very small indeed, as you will note when referring to them in detail.

As long as a Company pays regular dividends, the stockholders care very little, if any, what system is used in keeping a record of the finances. It is true they are desirous of knowing whether they get it "all" or not, and that the dividends are declared from net earnings ; but they employ an auditor to look after that part for them and rest contented upon receiving his yearly statement and affidavit that the books have been ex-

amined and found correct; but I trust such is not the feeling of those present this evening; and even at the risk of being a little wearisome, I will ask you to follow the system used by the Philadelphia Edison Company, as the same careful study and attention to details is given to the financial part of the business that is given to the mechanical portion.

You, of course, are aware that in Double Entry book-keeping every Debit must have a Credit and *vice versa*, and that the Debit side of the Ledger must be either Resources or Losses and that the Credit side, either Liabilities or Gains.

You have heard the Chief of the Meter Department tell you about the weighing of plates by two weighers, who are not allowed to compare notes; well from these weights he calculates the lamp or horse power hours, enters the same in books provided foi that purpose, which become the books of original entry. I mention this fact, as you all may not know, that in a suit at Court it is the first books in which an entry or account is made, called as above "Books of original entry," that must be produced and the accuracy of the account sworn to on what is written there; so you see books of original entry are important to preserve. After entering the bills in these books, they are transmitted to the General Agent for entry in the Consumer's Ledger, each individual's account debited or charged, and the amount credited to Light and Power.

The first thing every morning, the General Agent takes the Cashier's Cash Book and credits the Consumers' account for all bills paid the previous day, and charges the amount to the Treasurer. Later on when referring in a similar way to our Mdse. Department, you will see how utterly futile it would be for any employe to take advantage of the Company, as he would have to have so many accomplices, that the returns would be too small for the risk. After posting the amounts paid, attention is given to those customers whose bills were rendered seven days previous and not yet paid; a polite circular letter is sent to these delinquents reminding them that their bill has not yet been paid, and that they have three days more in which to pay it, or the current will be cut off; at the end of ten days, if not yet paid, notice is given the Meter Department to cut them off, so that we only lose this bill and ten days current if a customer intends to defraud us. If cut off, the account is immediately placed in Legal Collections and in a few days our Counsel is after them.

This iron clad rule and system is severely criticized; but one of the secrets of success in business is, to avoid trusting too much on book accounts, for many an insolvent man can trace his downfall in business to his endless, which in time grow to be worthless accounts. In fact, it is generally not so much in the quantity of the commodity sold, as it is in getting the money for that which has been sold, that leads to success.

Prompt collections are very essential to financial success (in not only electric lighting, but any other business); otherwise, when the Board of Directors meet to declare a dividend, the profit may only be on paper and not in the bank, it being tied up in a lot of uncollected, and in a great many instances uncollectible bills, as it is harder to collect five or six

bills than it is to collect one; hence you swell your list of bad accounts and decrease your quick assets.

How much easier it is for us to pay our bills within a reasonable time after they have been presented, than it is to pay them after the bills have accumulated.

In our Mdse. Department more time is given, as most business is done on 60 and 90 day bills. We endeavor, however, to have our customers pay on the first of the month following date of bill but we extend the time to the regular pay day, which with most concerns is from the 15th to the 20th of the month; but if the bills are not paid in 60 days, and in a few specially good concerns 90 days (the extreme limit of credit), the Executive and Finance Committee are consulted and the account transferred to Legal Collections; and before again opening the account, we insist upon being paid the cost of collecting the previous account. The result is, they are forever afterwards prompt in remitting for goods purchased. It is true users of lamps and wiring firms are somewhat compelled to buy their Edison commodities from us; but there is so much laxity in collecting accounts in most businesses, that the majority of large concerns admire prompt collections. It is generally the man with a small bank account, who is feeling somewhat dubious about his credit, that objects and get mad.

I should state here, that in case a Light and Power consumer, whose account has been transferred to Legal Collections, wants current again, a deposit according to the size of previous bills is required, before again replacing the fuses; and as long as the fuses remain in the cut-outs, this deposit remains with the Company. The customer is never given the second opportunity to default in payment.

The result of prompt collections is as follows:—

In 1894 the bills written for light power amounted to many thousands of dollars, but we failed to collect only $385.98. The bills written for Merchandise amounted to nearly $78,000.00, and we failed to collect $11.98. The 'proof of the pudding is in the eating'.

From the Sales Book the Store Clerk posts the Accounts Receivable Ledger, that is, charges the customer's account and credits Merchandise; and from the Cashier's Cash book credits the customers' accounts with the amount paid and charges the Treasurer. By transfer vouchers, the amounts charged to Treasurer on both the Accounts Receivable and the Light and Power Ledgers are transferred at the end of each month to the General Ledger kept by him. You see by this that both these Ledgers lead up to the Treasurer's books and have to balance each month. This system readily commends itself as an exceedingly good one. The Treasurer must account for all that is charged to him by two different persons in separate departments, and not under his control.

Having examined the method of entering that which has been sold and guarding the cash which has been received, we will pass on to expenses and see what care is taken to carefully charge every cent spent to the proper department, and not make one department suffer for the benefit of another.

There is no use of "juggling" with accounts so as to have a "good" annual financial statement that does not tell the exact truth ; better have each account tell you exactly the expense incurred ; you then know, the Directors and Stockholders know just how your finances stand. A great many surplus accounts are only on paper, and this thought invariably occurs to me when looking over a statement, showing a surplus account, and wonder how much of it really exists. I fancy that in a great many cases the money has been spent in betterments ; or more properly speaking, renewals.

Before taking up the Expense Journal, which shows the total as well as the detail business for the month, let us look into the system of ordering and checking the bills.

The foreman or person in charge makes out a Station order for what is wanted. This is approved by the Head of his Department, and the cost estimated. It is then sent to the order clerk, and a regular order, in duplicate, is made out and presented to the Secretary; if he has any doubts as to the expenditure, it is turned over to the President. The bill for the material is checked by the man who received the material, approved by the Head of Department and the prices checked and extensions verified by the Order Clerk, who places it in a voucher ; after the Secretary has seen that the amount has been charged to the proper account or accounts, it is then approved by the President ; or, if Merchandise account, by the Secretary and turned over to the Treasurer for entry in Expense Journal. By the time the order and bill have passed through this system, which is commonly called "red tape", you feel sure that it is a proper expenditure at a proper price.

The thought at once occurs to you that this is expensive, requiring an extra clerk. By having good conscientious men who desire to do a full day's work for a fair return in wages, it is done by the regular force that must necessarily be employed. Hence the only expense incurred is the printer's bill, that does not amount to much ; and we even get back this small cost, with a profit as the printing is done by a motor run by current from our Central Station.

The Expense Account is divided into Constant General Expenses, Operating Supplies and Expenses and Repairs.

Constant General Expenses include such items as rent, insurance, taxes, etc. which are constant. Corporations seem to be taxed at every turn, and it is a constant source of annoyance and expense. Taxes are like the poor, "always with us."

Operating Supplies and Expenses include such items as Coal, Lamp Renewals, Workshop Supplies, Meter Expense and wages paid for operating Dynamo and Engine Rooms, &c., &c. The expenses of the Boiler Room, you will recall, were charged to Coal Account.

In 1894 the expenses of these three subdivisions amounted to nearly $210,000.00, of which amount $89,704.53 was for wages paid to the men in the works alone. Of the total amount of expenses, $48,019.62 or 8.2 per cent. was expended for Constant General Expenses, $137,922.00 or 65.8 per cent. for Operating Supplies and Expenses and only $22,953.16 or 10.9 per

cent. for Repairs to Machinery, Piping, Station, Electrical Apparatus and Street Repairs and Maintenance. Of this amount, a little over $9,000.00 was for Street Repairs and Maintenance, leaving only $13,000.00 or about 6 per cent. of actual expenses for the balance ; and when you consider that the City authorities will not issue a general permit, as they do in other cities, but make us take out a permit for each hole, for which $4.00 must be paid, and that the streets under which our tubes are laid have improved pavements guaranteed for 10 years, hence the repaving must be done by the contractors, this amount is small ; and during the winter months the work must be done at night, thus making the work still more expensive.

This Station has been running continuously for 6 years and last year the repairs to the Station were only $1,008.26, Repairs to Electric Apparatus $5,428.15, Steam, Water and Blast Piping $3,238.85 and Steam Machinery $4,169.29.

This Repair Account has been itemized for two reasons, 1st : It may prove interesting to you to know these proportions.

2nd : To show the result of carefully selecting and securing the best when building and equipping a Station.

In connection with this matter it is, of course, conceded that all depends upon the ability of the Supervising Engineer and General Manager to select the "best" and sufficient "sand" to insist that the "best" shall be delivered. Giving contracts to the lowest bidders is a bad practice and the most expensive, as will be shown by the careful examination of the repair account of many an industry.

If the policy of "An ounce of prevention is worth a pound of cure" had not been faithfully adhered to, the Repair account of this Company would no doubt be still smaller; but the time surely arrives when you pay for violating the laws with compound interest added. Then the dividend is probably passed or the borrowing from banks resorted to.

In the items charged to Operating Supplies and Expenses, which you will recall as amounting to 65.8 per cent. of the total expenses, Lamp Renewals amounted to $15,786.44, or 7.5 per cent. of total expenses, and nearly 1 per cent. on the capital invested. This matter has been and is now receiving very serious consideration by Managers of Central Stations.

Upon investigating this matter, seven Managers of Central Stations kindly responded to my inquiry; and I find three are still furnishing free Lamp Renewals and four are now charging for them or permitting the customers to purchase where they please. One Company having only an installation of about 2,500 lamps, renewed nearly 10,000 lamps, which is a very heavy expense. I know from examination, that high potential and not bad lamps, is the cause of this. The average potential was 12½ per cent. high. (Paper of A. D. Page, Incandescent Lamps—their use and abuse—.)

The average number of lamps (not including motors) we had connected during the whole of 1894, was equivalent to 58,399 sixteens ; and we renewed 64,596, or the quivalent in sixteens of 68,377, making the renewals 1.1 lamps for every lamp connected, and the ratio of cost per lamp connected 27 cents for the year.

Some consumers will not even take the trouble to return their blackened lamps to be exchanged for new ones; hence we found it good policy to, once each year, take out every lamp a customer has and put in new ones. These old lamps are tested by a photometer, and all that are 15 c. p. and above we put back into stock.

When this Company was first started, services were put in and lamps installed, as well as renewed, free of charge; but when reducing the price of current, the Board of Directors found it necessary to charge for the service at actual cost and for the first installation of lamps; but continued to renew them free, when returned with the glass unbroken. It is still, however, a question in the minds of some of the Directors, that the expense of renewals should be a part of the customers' expense and not of the Operating Expenses of the Station. It may be necessary to erase this item from the books of the Company when endeavoring to reduce expenses still further to meet the price of $1.00 gas; but if Central Station customers should adopt the bad practice of isolated plant owners, of trying to get life instead of light out of the lamps with the least possible amount of energy, it will become a much more serious matter to the Company than the expense of renewing lamps; and your customers will cease to be your best advertisers. To illustrate this, permit, me to mention a case that occurred not long ago. A prominent merchant on Chestnut St. rented a store, the former occupant of which had an isolated plant; the plant was discarded as the benefits from using our Central Station current had been experienced by the party in question; but as he got the 4 Watt lamps formerly used on the plant; almost for nothing, he decided that he would use them and replace them with the regular Station 3.1 Watt lamps, as they burned out. The lamps were old and the light did not give satisfaction, but he insisted that it was economy to use them. It didn't take him long to change his mind and install the high economy lamp, upon receiving his first bill. 116–16 c. p. lamps were in the store. Presuming that they only took .6 Amperes and burned 3.81 hours per day (which is estimated from bill), the additional amount of current for which he paid was 67 Amperes per day and for 26 week days, the period covered by the bill, the total amount was a little over 1700 Amperes, making a difference of about $29.00 in his bill. The lamps were changed at once, the light and the next bill satisfactory. This is only one case; with some 1700 customers, what would be the result? The problem is not worked out by the simple rule of three, but by common sense and good business judgment.

In examining Constant General Expenses, such items as Salaries of Officers, Rent, Taxes and Royalty, &c. &c., which while necessarily a part of the expenses of an electric lighting company, they add to the expense of making the light and power, but do not enter into the expense of isolated plant. There are also other items that enter into the expenses of a Central Station and not into the expenses of an isolated plant; but I am not going into details, as these are sufficient for comparison.

This, however, naturally raises the question; does it not cost less to make your own light than to take it from a Central Station?

The question is easily answered by the fact, that the unit of expense is less when manufacturing large quantities than when manufacturing small quantities. A Station having the equivalent of 100,000 lamps attached can produce the light per lamp hour cheaper than a Station of 10,000 lamps capacity. We know this from experience; it costs us less to-day to manufacture the light per lamp hour than it did four years ago. Hence you can readily see that, if the owner of an isolated plant of 100 to 1000 light capacity, properly charges every item of expense incurred by reason of the operation of the plant, he cannot produce his light as cheaply as a large Station. This is one of the principal reasons why even large and extensive enterprises combine and form what is commonly called a "Trust," It is true some few endeavor to restrict production and thus increase the profits; but in the majority of cases, increased profits can be derived from honest combinations, and even lessen the cost to consumers by reason of such combinations.

But returning to the question of an isolated plant; it is the firm belief of leading managers that it is only a question of time, when it will be just as absurd to install an independent electric light plant, where you can get current at a fair price from a Central Station, as it would be for a person to install a gas plant, when they have gas mains in front of the door.

I have mentioned before the average number of lamps connected during the year 1894; but the average number of lamps and motors connected to the Station was the equivalent of 86,242 sixteens; and the total output was 45,947,690 lamp hours and 1,022,101 H. P. hours, or a total of 61,279,205 lamp hours; and as a 16 c. p. lamp is equal to about a 5 foot gas burner, the output in gas measurement would be something over 300,000,000 cubic feet.

Owing to many lamps being in Office Buildings, where the hours are short and very little artificial light is used during the summer months, and this also is true of our dwelling houses, that are closed for five or six months in the year, the average burning per lamp per working day was only 2.27 hours.

We find our expenses average about $3.00 per lamp per year; this means that with 100,000 lamps attached (the full capacity of this Station,) every lamp must burn at least 2 hours per working day during the year at our present rate, to enable the Company to continue paying 8 per cent. dividends, which is a moderate dividend for a manufacturing plant to pay. This leaves no surplus for bad debts or contingencies.

During 1894 the coal delivered on the scales, less the difference between that in the bunker, Dec. 31st, 1893 and 1894, amounted to 16,881 tons, or about 46.8 tons burned every day in the year. The total amount charged to Coal Account was $66,070.38, making the cost about $3.91 per ton.

The value of your consumers and the Coal Account are two very important items to consider in connection with Finances of Electric Lighting: and with an underground system, also Street Repairs and Maintenance.

The question of meters is now one of absorbing interest; and as soon as a good mechanical meter is found, that will register somewhere near the correct amount of current consumed, when subjected to all kinds of rough treatment and temperature, this item of expense will be materially reduced, possibly a saving of 50 per cent. effected.

At first the price charged per 16 c. p. lamp hour was 1⅛ cents; or according to gas measurement, $2.25 per M. cu. ft. Gas was then selling at $1.50. The then General Manager recognizing that the competition had to be squarely met, got the Board of Directors to reduce the price, October, 1890, to equal gas, or ¾ of a cent per 16 c. p. lamp hour, which is lower than the price charged in any other City in the United States, or I think, in the world. An immediate increase in our business was the result of this decrease in price. This makes our income about 1¼ cents per Ampere hour, or 30 cents per Ampere day; but the reduction of 33⅓ per cent. had to be met and equalized by either 33⅓ per cent. increase in business plus the expense of handling the increase, or by both increased business and decrease in expenses, to maintain the same revenue; hence the reason for charging for Service Connection and the first installation of lamps, to which reference was made a few minutes ago.

The Meter and cut-out are not paid for, and remain the property of this Company at all times. Then by a careful analysis of the value of all our consumers, which is done at certain intervals, it was found that some of them, by reason of a limited use of their lights, the Company did not receive from them the cost of maintenance, which you will recall was about $3.00 per year, or a trifle less than 1 cent per day. This study of the cost of maintaining and revenue derived per lamp and H. P. hour is very essential to the success of Electric Lighting. You can readily understand that if the revenue per lamp or H. P. or both, does not equal the cost, you are simply supplying that current at a loss. The Bullitt Building with its 2200 lights was not as profitable as 110 consumers, having 20 lights each. Small consumers are more profitable, as a rule, for the reason that they generally have use for every lamp installed, which means a revenue of 3 to 6 cents per day per lamp against a cent or less revenue from a consumer having a large number of lamps. But the most unprofitable of all are dwelling houses, that are open only about 5 months in the year and closed 7, which means that you carry machinery for 7 months without any return, to supply the lights for 5 months, Churches, other than Roman Catholics, are also considered unprofitable, owing to their limited use of current; but there is this to be said in favor of the churches, they help a Company earn the expenses of running the Station on Sundays, and their use during the week is generally after the maximum load is off.

Taking in consideration all the points above mentioned, the reduction in price, cost and revenue, it was found necessary to have consumers guarantee a minimum payment equal to, at least, the cost of maintainance. That is, if a customer has less than 20-16 c. p. lamps or 2 H. P. or or less, the guarantee is $4.62 each four weeks or $60.00 per year; and above that number, 6 cents per week per c. p. lamp and 60 cents per week

per H. P. This means that the customer pays for the cost of keeping machinery ready to supply him with current day and night, Sundays and Holidays and as the guarantee for lamps amounts to $3.13 per year, a profit of 13 cents is pocketed by the Company.

Another point of weakness was developed by an analysis of the motor business for October, 1894. We found that freight elevators below 10 H. P. were unprofitable, as the revenue derived was not adequate to the service rendered. That is, it would be much more profitable to supply 75 lamps than the equivalent, a five H. P. Motor, taking as a basis 15 lamps per H. P. At the present minimum rate, a lamp value is 26 cents per month, whereas a motor is only 18 cents. We found that Lamp Renewals amounted to 27 cents per lamp per year, 2¼ cents per month, so that at least a lamp is worth 23¾ cents, or 5¾ cents better than 1 H. P. Motor.

Before the introduction of a motor, it cost for a man's labor to look after the elevator, $1.50 per day; therefore the guarantee for elevator motors under 10 H. P. was made $1.00 per day.

The leakage between the reported Dynamo output and the meter returns is now receiving careful investigation by a Committee; but sufficient data has not yet been gathered to enable me to speak of it to-night, but it is pertinent to the subject and worries Managers of Electric Light Companies.

A few remarks about the Log Book and the Board of Control would perhaps be proper, but I find that my time is almost up and the paper already quite long; therefore in conclusion, I thank you for your kind attention and refer you for further consideration of this subject to a paper written by Prof. Marks some years ago, entitled, "How to get paying loads for Stations;" and will apply the closing remarks of a learned law professor to his students, to close my talk. "Gentlemen: Move Heaven: Move Earth; to carry the jury." This was the object to be attained by studying law—The object to be attained by studying Finance is, Gentlemen: Move Heaven: Move Earth, to pay dividends.

HISTORY OF THE EDISON ELECTRIC LIGHT CO. OF PHILADELPHIA,

BY

PROFESSOR WM. D. MARKS.

PRESIDENT,

In talking over the matter of a course of lectures, I agreed with the committee to tell the story of the building of this station, as a final lecture. In doing that, I will have to take you into my confidence and tell you a good many things that perhaps you have never known before; and I will have to do another thing that I regret to do--I will have to talk a great deal about myself, but it is impossible to avoid this where one has been engineer, general manager and president of a corporation, starting with nothing at all and then ending up with the largest isolated station in the world—it is impossible for me to do otherwise than to talk about myself a good deal.

The thing that has rendered this station possible is this little thing that you see over your heads—the Edison electric light invented by Thomas A. Edison. Out of that has grown everything that you see around you.

Within a short time the Courts of the United States have wrongfully taken away from Edison the last two years of his patent, but it does not make much difference to him, because long before the courts got at it and decided against him, the financiers of New York had practically absorbed the thing and left him to work on other inventions.

In 1884, the Franklin Institute gave an exhibition which was the first public appearance of any note of the incandescent light in Philadelphia.

That exhibition was visited by all the people of Philadelphia and a great many from outside of it; and as a result, attention was directed to the Incandescent light.

A party of five gentlemen, knowing little or nothing of science, but having seen the light and admired it, and having great confidence in Edison's genius, got together and organized an electric lighting company. These gentlemen were Mr. B. K. Jamison, Mr. Samuel B. Huey, Mr. Charles M. Swain, Henry M. Dechert and Amos R. Little.

Their first plan was a very modest one, indeed. They were going to subscribe one hundred thousand dollars, and with their friends assistance, they were going to put up a station that would furnish ten thousand lights. Well, they thought this matter over and deliberated some time—for a year or so—this was in 1886—when they came together and finally decided, after conferring with a good many, amongst others myself, to increase the capital of this station to a million dollars, as the New York Station was thinking of doing the same at that time—in fact had done it.

After finally deciding on a million dollars and obtaining sufficient subscriptions, they decided to complete the station.

At that time I was called in. A million dollars was supposed to be sufficient to build a station which would light about 25,000 to 30,000 lights. In receiving my instructions from the leading or managing director, I was instructed to procure lots of about the same area as the Twenty-sixth Street Station in New York city, which was then in process of erection. On measuring that up, I found that they had about 7,000 to 8,000 square feet of surface—of floor surface—and so we began our search for real estate, and finally landed upon this piece of property, the inducement being that the station would be located in the midst of those most likely to use and consume the light.

The main object of locating a station right in the heart of the consumers section was to save copper. The most expensive thing about a station is the immense amount of copper that is required to carry the currents, not only in the streets, but also in the building itself.

Upon looking into the plans of those who had gone before me, I was by no means satisfied that 30,000 lights was all that could be gotten into so limited an area as was allotted to me. Little by little in thinking the matter over, my ideas expanded to 50,000, from that to 100,000, and finally to 150,000, which is the size upon which this station is designed to-day. We have at this present moment, in fact, 94,500 lights or in their equivlents, either actually attached or about to be attached. It will not be very long before we have 100,000 attached, which is all that the copper in the streets can carry. We can put more machinery into this station—enough to carry 150,000 lights, but we cannot carry the current out into the streets—the copper that leads out into the streets will limit us in that direction.

Of course, after fixing on 150,000 attached lights and figuring the dimensions, I realized at once that, instead of building such engine houses and stations as you ordinarily see, or even such as are seen to-day in New York and in Boston, that I would have to build something of extraordinary strength. The weight on our boiler floors is about 4,000,000 pounds. The weight on this floor on which you are sitting here is about

1,000,000 pounds. Your dynamos weigh 18 tons apiece, and your engines—your larger ones—30 odd tons. We call the 1,000 horse power the larger ones. So that you see that the weight supported by the real estate that we are on is something enormous.

It occurred to me that nothing but a rock would support such weight. We had no rock. We had bored holes down in this lot to a depth of 20 to 25 feet, and the best we could find was water gravel. That is regarded as a good foundation in Philadelphia and elsewhere, but no such foundation as we wanted. So, we had to make our rock. All of the clay lying over the gravel was excavated and borings were made for 18 feet below the curbstone. When we got down there, in cases there were pockets where it was lower than 18 feet. So, instead of laying down a slab, a monolith of cement and granite of a uniform thickness of four feet, you would find, if you could examine it, that it was in some places 10 feet thick, and in the thinnest place four feet thick. This slab is 70 feet looking east and west, and 100 feet north and south, and on it are placed foundation walls made of granite in cement mortar five feet in thickness all around the outside. Above it is reared brick walls beginning with four feet in thickness and tapering off according to the load as we go towards the top.

The history of this station has been one of continued trouble and obstruction. The first thing our contractor, Mr. Grubb, did, after he had got his hole dug and his foundation started, was to fail. He industriously tried to put in anything and everything but what he had agreed to in the way of concrete, and I came down here and lived on the curbstone and saw that he did not put anything else in, and as he found he had to carry out his contract, he settled the matter by failing. That made it necessary for me to put in this slab and this foundation myself, which I promptly did, arranging to come here early in the morning and generally leaving here after midnight.

We had not got well along with the foundations, before the water that we had thought of and considered necessary, was brought before the city authorities. We intended to put in 10,000 horse power. We were to start very modestly with only 1,000, but 10,000 was what was going in. I went before the water department; was referred to city councils. The committee met with a good chance for a strike. Their ultimatum was $2,000 minimum payment per year, and $2.00 per horse power for every horse power we put in. There was no use talking about anything of that sort. That would be simply working to support our city fathers. And so I undertook to dig a well out front here. I made the usual contract. Our board is very strong on contracts. It always wants a contract and is not satisfied unless a contract is made.

One contractor dug until the water came up about a foot and announced he could not dig any more. I asked him why he did not pump it out. He said he had. He had a pulsometer pump there and it pumped a little bit of a stream about an inch thick, but once in a while a bit of gravel got in and he would have to go down and fix it up, and the water would come up where it was before. Then I went and made a contract with another man. This was a man who did work on a larger scale, and

he brought a locomotive boiler here ; and he brought a bigger pump and started in.

Now, this well runs down a depth of 40 feet below the curbstone, and the curbstone is 30 feet above the mean low water mark of the Delaware. I had looked on an old map of the city which showed me that along Sansom street, in this neighborhood, ran a stream which emptied into the Delaware, and I hoped to strike its gravel bed, so the water, coming from the Delaware, would flow in, so we would not have to ask the city water works, and would get a surer supply.

I assure you I was in great trouble when the second man, the greatest and best well digger in Philadelphia, announced that he could not get deeper. We had three feet of water and he could not pump any more. We had to have water enough for this station, and I went to the north part of the city and investigated the wells there. I found a man who had a mining pump which he said would throw 40,000 gallons an hour. I bought it, and a 50 horse power boiler, an upright one, built over it a smoke stack—guessing at it, I should say the top was 40 feet from the ground—tallest thing you ever saw. The city authorities came along and said they would not have a boiler in the street, so I set it up in the back alley. At first they did not catch us there. They were not vigilant enough. And we carried the steam pipe right along to the front part, and I fitted up the lower end of the mining pump so we could lower it down as the well went down. As fast as the men dug out, the pumping cylinder would go down and the steam cylinder would stay where it was. It was quite a success. I shall never forget the last night and day. I did not leave I think, for 36 hours. I was determined we should get water enough here. I was determined that well should be thoroughly tested. Little by little the stream of water came in larger and larger, until finally, going down to the bottom of the well myself, I found streams larger than my arm pouring in from the gravel. The steam boiler was made with an artificial draft, and the men down below were getting scared because the water was coming in so. The pump was jumping, and we went along that afternoon splendidly, pouring that water out into the street through an 8 inch delivery pipe. That night, I made up my mind we had to make our rush. We kept the boiler going. The boiler was dancing jigs and the pump was pumping for all there was in it, and Sansom street from curb to curb was full of water pouring into the sewers and down into Ninth street. I was there at the boiler to cheer up the men ; and this thing went on until the morning, and finally our counsel came up in the morning and said, "what have you been doing? The mayor came to me and said you must stop filling up Sansom street with water."

We had pumped 40,000 gallons of water per hour for 28 hours, so I very submissively said, "please tell the mayor we will stop." We did not meddle with that boiler. We were afraid to. We drew the fires. I was afraid something would happen. That is the way we got our water. It saves us $20,000 a year now—quite an important saving.

It was in the spring of 1888, that the station proper— the building you are in—was begun. But, in the autumn of 1887, a large amount of

pipe tubing—I call it pipe—we call it tubing here—was laid, inside of which is the underground conductors of the Edison Company. And there again we met with some obstructions.

Although I had very carefully devised plans presented to me showing that, in other cities, the Edison Company had been allowed to open up streets half the street in width and lay its conductors down; I was told immediately by the city electrical authorities, that under no condition could we have a ditch over three feet in width and but two feet in most places. I argued and showed plans. They were obdurate. And so we have laid them one above the other. There was no help for it. It was either that or not at all. When the time came for laying the tubing our time was very brief, because they put a stopping place at the first of December, and if we did not get into the streets by then we did not know what the Councils might do in the intervening time. So, I was instructed to lay all the pipe I could and occupy all of the ground I could and force things so nobody else could get in, and we did. We had two gangs at work—one day and one night, and we kept it up to the last moment. We did not stop until nearly Christmas. I used to be notified about once a week that we were proceeding in a very irregular way, and I used to go down and arrange with our counsel as to what should be done—asking what was the punishment for contempt of the Director of Public Works. If I was arrested I wanted to be able to get off, and if I was to be fined, I wanted the Company to pay the fine. This they agreed to, and we went on until Christmas and in the Spring the same way, and we succeeded in occupying the best portions of the City of Philadelphia by doing that.

In March, 1888, began the building of the station building. After the foundations were pretty well finished, I was called up by the Board of Directors one day, and instead of going ahead as I had anticipated and completing the station as it stands here now, I was told that they had been conferring on the matter, and they had decided that they would build a half station. They would build half and see what I could do with it, and if it was all right, they would build the whole. They did this for purely financial reasons. They professed to have no idea of the engineering construction and considerations that came in. The result was we built a station, those of you who have been here for some time know, that had a wooden roof about half the height of the present one, and out of that stuck the iron smokestacks and the exhaust pipes, and you all know too, that when we got to going in the evening, everything in the neighborhood was going. All the windows and buildings were dancing jigs. The reason for that was a very peculiar phenomenon and one I had never come in contact with before in my life.

In arranging the foundations, it was my determination to have no vibration through them. It never occurred to me that the vibrations of the atmosphere would shake windows and doors and buildings; but we soon found with our 36 inch exhaust pipes, the air above us was shaking like a bowl full of jelly, and if the wind blew from the south or southwest, the boarders of the Continental Hotel had a sort of shivaree played on their

windows all night long, and the proprietor was over to see me next day. But it did not make much difference which way it blew; we had a ramshackle old building next to us called the Irving House that was always going. They threatened to sue us, and we effected a compromise on my solemn assertion to the Board of Directors that, if they would let me build this station up, they would have no trouble with atmospheric vibrations; and now it is hardly perceptible.

While this was going on, and within a very brief period after the Board of Directors had cut me down with the remark and order that we would not build but a half station, the New York people became vastly interested. We had departed from their counsels. Instead of putting in little bits of dynamos and rows of armature shafts against each other, I had put in No. 60's, twice as big, and instead of fixing everything so you could not get an armature out, as they have in New York to-day; we got them up so you could swing an armature out. Then we had our dynamos closer together; our engines were simply very broad shouldered dwarfs, specially redesigned by Armington & Sims according to dimensions prescribed by myself. In everything we had enormously increased the power and size and the steam pressures. They were confident in New York—the authorities—that this station could not even begin to operate, much less be operated after it was fairly under way, at a commercial profit. There arose a tremendous rumpus over the thing, and they went to Edison, and a sort of court of inquiry was held at Edison's laboratory in Orange, New Jersey. We were all convened together in his beautiful laboratory there, and the whole matter was taken up with Edison wearing just as judicial an expression on his face as he could get on, and everybody stating their reasons and facts. As a result of this careful inquiry, Mr. Edison, who had hitherto taken no part in it, decided favorably to the Philadelphia Edison Company's designs, stating that they were much better than the New York designs, and would yield 33 per cent. more return for the same expenditure of money. He wrote this out in his own handwriting (exhibiting a framed piece of paper) and I picked it up as I left the room, and brought it on to Philadelphia and had it framed, thinking that Mr. Edison's autograph, and particularly a little writing in his own hand, would be very valuable as a possession some day, particularly bearing on my own engineering work.

So the station was not stopped. They fully intended to stop the building of this station.

Matters went on rather smoothly after that until the question came up of boilers. Amongst the various bids was one of Abendroth & Root Manufacturing Co. of New York City. It was a very attractive bid. It was attractive first of all because it was much lower than any of the others. Next, they promised what seemed hard to get in water tube on steam boilers—great flexibility. The boiler was so flexible in its construction that it would yield to all temperature strains, and if you found it necessary to fire up the boiler and get steam in 15 minutes—the Babcock and Wilcox might break, but this boiler would theoretically act like a charm.

The first battery of boilers which they put in for us was designed by the Root People—the people under Root, but he died and a new engineer was put in, and he decided that he not only would have what old Mr. Root had done, but a vastly stronger boiler. In the meantime, the first battery having worked to tolerable satisfaction we ordered three more batteries, one after the other in quick succession. Business came to us far more rapidly than we had any hope of finding it. These boilers had strength. They were made so strong and stiff, and the bolts were bound so tightly, and everything was so clamped that every time the slightest movement occurred either a bolt had to break or a bend had to be crushed, and the result was, as each had 27,000 pounds of water in it, that the hot scalding water and steam were thrown out under a pressure of 135 pounds to the square inch, and I am very sorry to say sometimes resulting in serious injury, and in fact in the death of one of the men.

There was no help for it apparently. Your engineer (myself) protested against payment for those batteries of boilers unavailingly. The contractor had assured the then president that it was a case of bad temper—the worst kind of bad temper on the part of the engineer. He assured him, moreover, that the local agent had confidently assured him that Professor Marks was a dangerous man, that he did not dare to go into that station, and he could bring the agent before the board, and have him swear to that, and he did bring him before the board and had him swear to it,—because I had talked to that gentleman and told him what I thought of him,—that I was in such a frame of mind, that his life was not safe,—and it ought not to have been, either! The President, on that assertion, paid for those boilers, whereupon Mr. Abendroth promptly withdrew all his men, carrying the money with him.

Then came a period when the city authorities interferred and threatened to shut down the station, in which case the investment of about a million dollars of our board and half a million on the part of other investors, would have gone for naught. There was nothing for it but, regardless of the present danger of anything happening to these boilers (that were to yield to temperature strains,) to remedy their defects. And I want to speak right now of the debt of gratitude which this company owes and the high esteem in which it holds the men who risked their lives in this work—Livingston, Organ and Joyce. They took this work. It was not such work that happens in the army, where a man is shot and that is the end of him, and where a battle happens occasionally. Day in and day out they stood to this work and did it systematically and coolly, facing the risk of being scalded to death. I do not think you will find braver men anywhere.

However, that was finished finally, and we have a big suit against Abendroth and Root, and we hope to get a lot of money for we have sued them for $34,500., and the jingle of the dollars in our stockholders pockets, will go a little ways towards making them satisfied.

After these difficulties had been conquered, it was much plainer sailing. We began to prosper greatly. The president of the company went over one day to New York City, while the profits were continually in-

creasing here, and came back with a modified form of contract with the New York Company, which showed on the next million dollars which they had decided to put in, a clear saving of $275,000. The board received the announcement in silence—they gasped—and one member of the board asked if there was any room to make any more. You can imagine the disappointment of the president. He thought somebody was going to say something complimentary. However, the modifications of the contract having been attained, the profits of the station being assured, it was decided to issue more stock and complete the station. The work on that was begun about two years ago, and you are sitting now at a height of about 130 feet above the pavement, with 800,000 pounds of coal immediately south of you, upborne on the foundations which I have described to you. I do not wish you to be frightened at all, but I wish to call your attention to the fact that if that engineering work and bricklaying and iron work of the whole station carrying these enormous loads had not been done upon honor and conscientiously, the weight and vibrations would cause the floors to sink and we would be one undistinguishable mass of boilers of dynamos and of engines, perhaps spreading over a large area, and to adjoining houses. So that you can have some conception of what boldness has been shown in building up this station to carry 150,000 lights A single mistake, and the engineer in charge is shown up, and he is the only one to blame. As long as the station goes along beautifully, the board says "See what we have done". But if anything goes wrong, it was the engineer—the President.

The station was completed, and with the completion of the station, came a period when what had long been in my mind was practicable. I had always felt that there were two forms of government, which were more or less successful or equally successful, if carried out properly. The first form of government is to find an absolute despot, who knows the business from end to end ; who is expected to go into everything and to look into everything ; with that, as long as he lives and has his health, almost any concern will do very well. The second form of government, and to me far the preferable one, is more or less of a republican form. In order to attain to this, a Board of Control was established here—a Board of Control consisting of the heads of departments. The object of this Board of Control was primarily to create a body of men who, while they were specialists each in his own department, and expected to attend thoroughly to it, at the same time would, by contact with the heads of the other departments, get a good general idea of the whole business You see at once then, that instead of the corporation being dependent for its prosperity, on a single man, who is supposed to know it all, it has a body of men, each one of whom is supposed to be easily first in his own department, and to gain by degrees a general knowledge of the affairs of the whole concern.

In addition to that, where men increase to the numbers that they do in all of these large corporations, it is impossible for any single individual to be around—to become personally acquainted with every man. He can talk to them, but the best talker is generally the worst worker. The

only way to know a man, is to spend time enough to see how he does his work, and the only man who really knows how much a man is worth, is the head of the department for whom he does work directly. It is possible that a head of a department—we are all frail—possibly may take a prejudice against a man. A man may do his work splendidly, and yet be personally a disagreeable man. If, in dealing with that man, the questions of his promotion, of his discharge, of his rate of pay, are taken up and discussed calmly by a board of—say half a dozen—it is a probable that, in the course of that discussion, if they will take pains enough, that the real facts will come out in the case of the individual, and that he will have nearly accurate justice done to him without any prejudice entering into the decision. I am glad to say that our Board of Control, which has been working for a year, has on one occasion corrected the president and he has accepted their correction. He was a little too quick about something he did and he took it back, when the board investigated it, and I know that they have corrected each other in many points, and I think that the men realize that, in a judicial body of that sort, though you may not have a perfect, yet there is a very fair guarantee of justice between them, and if the head drops out, the value of the stock of the corporation does not at once depreciate, for the very good reason that the stockholders realize that there is a body of men there, generally informed practically capable of carrying on the work.

Now referring to another point, and one which you have not been thrown in contact with at all—the politics of the Edison Company. You see that I am taking you into my confidence pretty deeply to-night. When this company was first organized, it applied for a license or a privilege to underlay the streets of the city of Philadelphia with its conductors. It employed counsel for the purpose of going before the proper authorities connected with the city councils, and he tells me he went before the city councils committee eighteen times, and every time was met by excuse after excuse, reason after reason, and any reason and every reason but the true one, for not granting the privilege to the Edison Company. Finally, a company called the Penn Company was organized. It was organized over in New Jersey, where nobody could investigate them. You have heard about them in the newspapers probably. And this Penn Company, which had not a dollar of money, was granted the privilege of underlaying the streets of Philadelphia. It had, however, a million of dollars of stock, which was held amongst politicians; and the Edison Company was forced to lease the right of underlaying the streets of Philadelphia from the Penn Company, though the streets were not owned by the Penn Company but by the citizens; and we are still forced to pay the Penn Company for the streets, and the privilege of doing our own work there at our own expense.

While we have been going on this way, we have been applying for the privilege of underlaying the streets in our own name. We have little parts all over Philadelphia—on Spruce street, Arch street, Third street, and a half dozen different places where the Edison Company can lay tubes in its own name, but, in the streets around this station, the Penn Com-

pany stills holds the right to underlay the streets of Philadelphia. We cannot get at our own tubes ; and our only help was to become in part at least a possessor of the Penn Company, and this is the way we are situated as to leases. We are really the only people that are leasing anything from the Penn Company.

We have to-day a bill in councils. Any of you who read the newspapers, political part of them, will see all sorts of editorials ; you will hear of this snake and that snake to be killed ; you will see pictures of boa-constrictors crawling into the City Hall with the Edison light on their tails. Let me assure you of one thing. If there was a job there—if the city councils were paid—nothing would be easier than the passage of a bill in favor of the Edison Company. The newspapers, with a few exceptions, are even more venal than many of the councilmen—the newspapers would not indulge in editorials about snakes and things—the bill would go through. I say this much to you, because you no doubt have been all of you very much interested indeed, at the horrible character which has been given to the Edison Company in a political way. If it really was what it is represented to be, it would not have any trouble at all. The newspapers would appeal to the councilmen to pass the bill, and it would be passed without a word.* I see my time is up, and thank you all for your kind attention.

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* The Edison Bill was finally passed and signed by the Mayor April 1st, 1895.